Instruments

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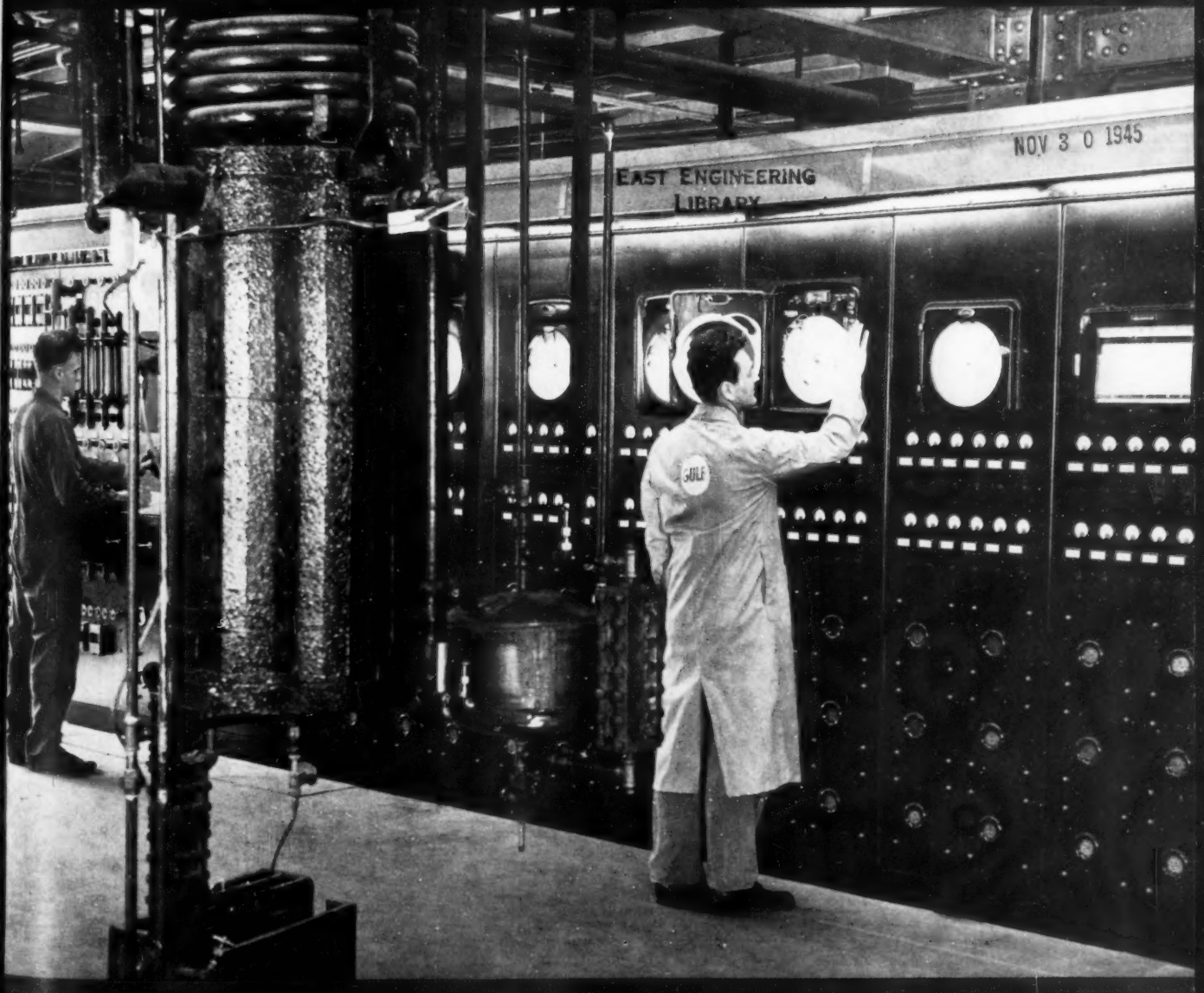

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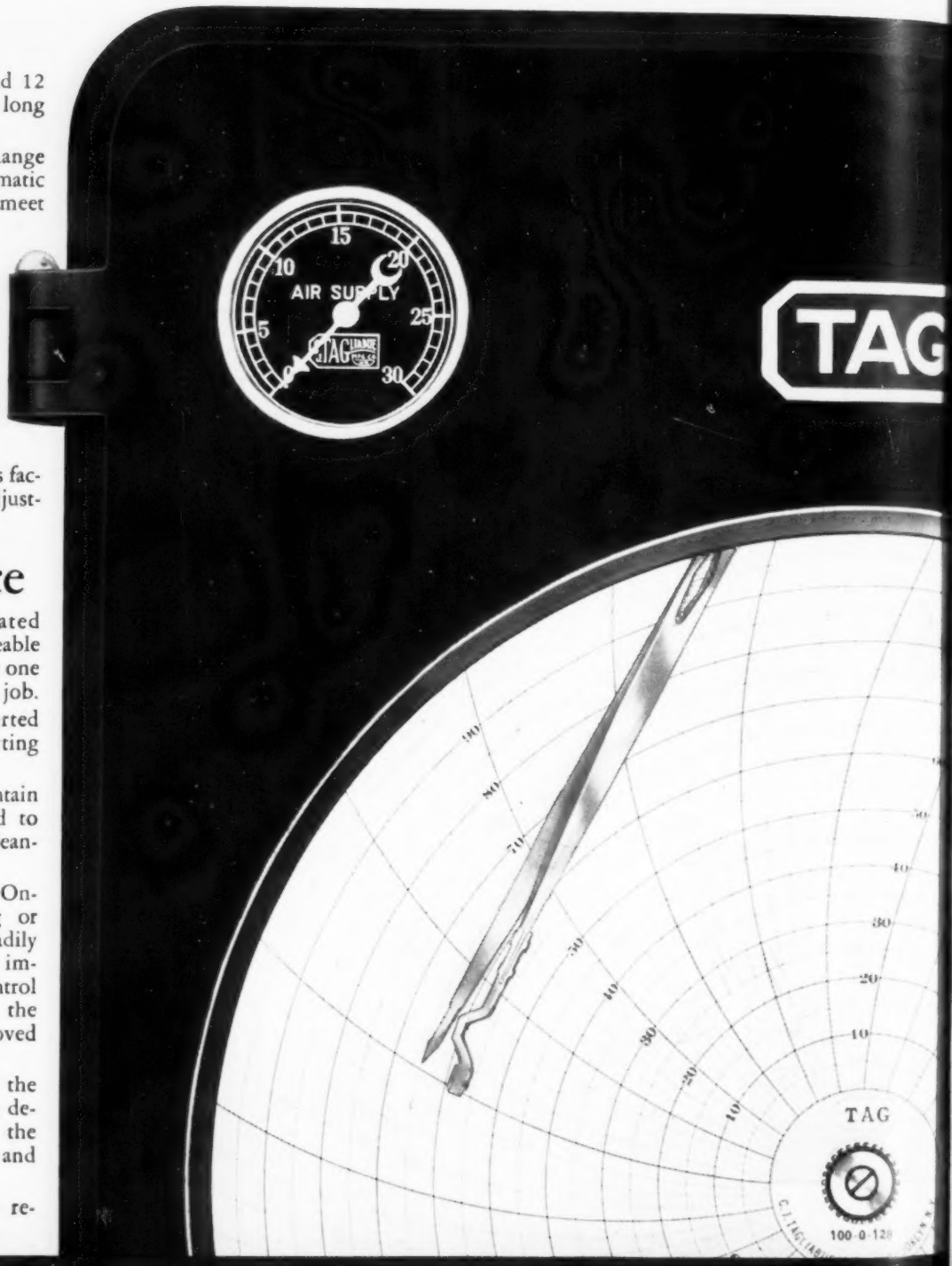

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Instruments

Vol. 18 November 1945 No. 11

Special Issue—A.I.S.-C.I.T. Conference on Instrumentation and the University

COVER: Pilot-plant control board at Gulf Research Laboratories, Harmarville, Penna. *(See page 802)*
Courtesy Gulf Research & Development Corp.

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Permission has been given by the Sponsors of the Conference (namely the Carnegie Institute of Technology and the Instrument Society of America) to reprint any or all of the above-listed papers, provided that credit be given to the Conference and mention made of dates, place and Sponsors.

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Education + Instrumentation = A Better World for All

"IN direct and indirect ways, the future careers of most *Instruments* subscribers will be affected by the AIS-CIT Conference to be held October 15-18. Next month's issue of *Instruments* will report the proceedings in stenographic completeness. Most regular features will be crowded out; even this editorial page will be used for a speech to be selected by the committee in charge . . ."

SO began last month's editorial. Such was the directive which governed your editor's plans for this issue. But this directive has just been changed: (1) no single speaker is to have his paper printed on this page and (2) all papers are to be printed in exactly the same order that they were presented. Therefore your humble servant, in the midst of editing 537 pages of typescript—the largest number ever to go in one issue—in the shortest time ever left for this monthly chore—has been directed to write an editorial as usual.

"As usual." Well, why not? Our *usual* comments are addressed to all subscribers in all occupational groups, not to educators alone. Our *usual* editorial comes from the heart rather than from the mind, so here is one that suggests itself:

They Met, Deliberated and Worked for You

THIS special issue of *Instruments* is devoted to the Proceedings of a Conference which was devoted to your welfare and advancement. Read it well! —MFB

Yes, read it well! Some of the titles, to be sure, will not attract all groups of readers, but we assure you that precious gems are to be found in all.

Example: we promised on this page in September, to give you exclusive articles on radar instrumentation principles, if possible by December. A month ahead of promise, you will find one by Dr. Williams.

Read the discussions, too! All were spontaneous — necessarily so because practically no one knew in advance the text of any paper.

As a rule, discussions from the floor make dull reading—as does the *Congressional Record* or any other verbatim report of oral exchanges. Far from dull are those in this issue: what you will read is the end-product of a process that began with cutting up 224 pages of the stenographic report carbon-copy and mailing pieces to discussers, with rules for condensation.

In these days when the more-or-less wise leaders of the great powers are holding conferences affecting the future of the human race, it is rash to apply the adjective "important" to one conference representing one segment of industry and one segment of education in one country. But historians might well note that during this period of disillusionment, while clashes of selfish groups make newspaper headlines, some two hundred people gave three days of their lives (plus travel time and expense in many cases) for the betterment of Instrument Men. THIS IS IMPORTANT. It is especially important because Instrument Men are not a pressure group. They are people in many walks of life—engineers, artisans, scientists, laborers, executives, educators, etc. They are you and you . . .

Although most participants were practical men, few dreamers, the atmosphere was one of idealism. Which is to say that most participants were hard-headed and tender-hearted. Human relations were stressed more than at most technical meetings; the complaint was voiced that business men and lawyers rule America and look down on engineers and scientists. One speaker said "We are responsible; we have never made ourselves prominent . . ." This went unanswered—probably because those who know the other side know that the argument is endless. The other side is that most business men and lawyers are underdogs, too; that most dictatorial top dogs gain power and money because they worship power and money as ends, are sufficiently cruel to climb on their brothers' shoulders, and are so devoid of sense of guilt that they not only pose as generous but fool themselves into believing they are supermen. You'll find mean, overbearing dictators among graduate engineers as well as among business men.

Now guess the affiliation of the man who said this:

"In general, training should be given in a much wider field than that in which the student intends to specialize. This is necessary . . . to *enable him to have a wider field of employment from which to choose.*"

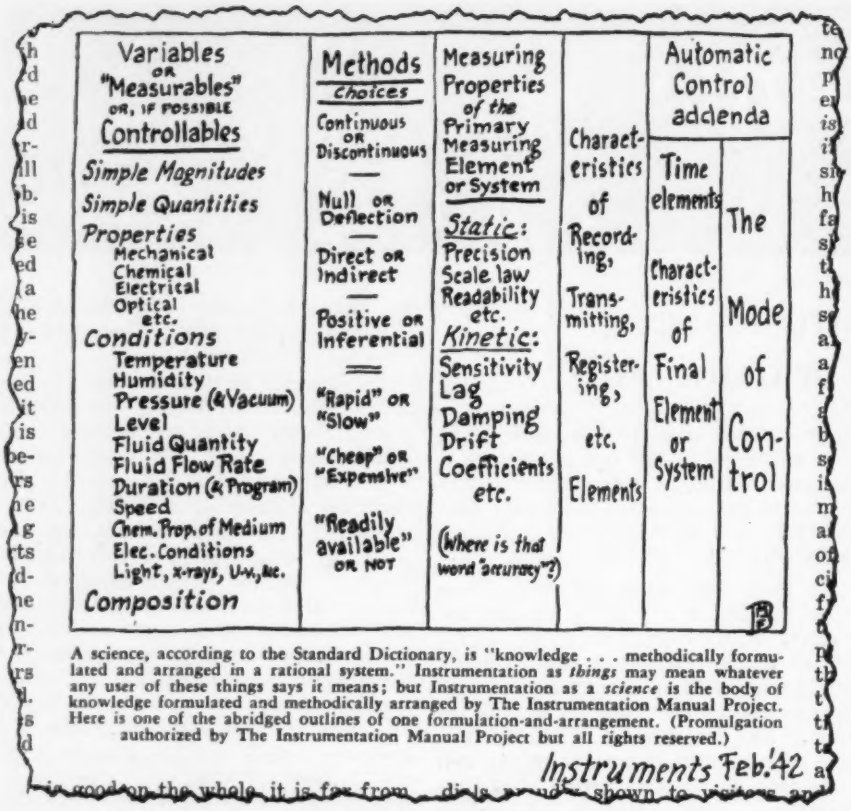
An educator anxious for the success of his students? Wrong and right. Wrong, because he is an employer (and a justly-famed one). Right, because he is a Trustee of M.I.T., where he taught electrical engineering 29 years ago.

Statistics are usually dull, but we want to congratulate the Arrangements Committee on the excellent occupational distribution of the speakers they invited: Education, 8; Armed Forces and government laboratories, 6; instrument manufacturing, 8; other manufacturing and public utilities, 8. The proportion of instrument-company spokesmen does not seem high when one remembers that the Conference dealt largely with university education and that instrument companies need scientists as well as salesmen, glass blowers, machinists, etc.

As for the occupations of the other 150 or 170 conferees, analyze them for yourself from the registration list. Education predominates, because Carnegie Tech was the place, Carnegie Tech one of the sponsors, and "University" half the theme. But the other half of the theme, namely "Instrumentation," was the magnet that drew busy men from hundreds or thousands of miles. At the Tuesday dinner the long-distance prize was awarded to Dr. Pompeo of Shell Lab in California; but on Wednesday Lt.-Com. Schliestett flew in from Europe. We've known both for years and, without asking them, we're ready to wager that neither came because of the word "University," both because of "Instrumentation."

Which reminds us that the more-and-more-frequently-uttered question "Just what is Instrumentation?" was put to us between formal sessions by a number of Conference members, including one invited speaker, who did not consider sufficiently exact or specific our 1924 assertion that Instrumentation is the science and technology of Measurement-and-Control. Sometimes we answered, "Well, then, Instrumentation is whatever you say it is—as far as you are concerned!"

And that, dear reader, goes for you. Not only will it help you in your career to ponder deeply over this question and try to formulate a specific definition of what Instrumentation means to you; but as you develop your own original ideas on the subject into a distinct body of data and doctrines, your resulting contribution may expand the sci-



A science, according to the Standard Dictionary, is "knowledge . . . methodically formulated and arranged in a rational system." Instrumentation as *things* may mean whatever any user of these things says it means; but Instrumentation as a *science* is the body of knowledge formulated and methodically arranged by The Instrumentation Manual Project. Here is one of the abridged outlines of one formulation-and-arrangement. (Promulgation authorized by The Instrumentation Manual Project but all rights reserved.)

Instruments Feb. '42

ence or technology in a unique and useful way. You need not be a highly-educated scientist to advance *any* new science or technology. (Think of Faraday, Edison, *et al.*) Even today, Instrumentation is still in its infancy. This is the proper occasion to reprint a statement which probably fewer than 2% of our present readers have read. It was made in the first lecture at the first (1942) Instrumentation Conference of the AAAS:

Not all of Instrumentation is exact science. Instrumentation is other things than even an infant science . . . It is at the same time an art . . . No simple answer can be given, because no simple description is possible of a phenomenon which has not yet assumed a definable shape: Instrumentation is like a fast-growing tree whose roots and branches are constantly multiplying. It is like the banyan tree which sends, from some of its branches, downward shoots which take root and eventually develop into accessory trunks so that the tree becomes a grove. No simple answer can be given by any individual today and accepted as true by all others, because among these others there have appeared in the last few years some twenty or thirty who each has contributed valuable roots or branches or accessory trunks (each the main trunk now!).

As you read the Conference proceedings you will note that various discussers as well as invited speakers expressed differing views of Instrumentation as a body of knowledge or of instrumentation as gadgets. There is no arbitrary limit to the number of different concepts: in the paper just quoted no fewer than 39 different definitions were listed, among them this one:

15. Instrumentation is the design, development, construction, sales engineering, specification, application, installation, operation and maintenance of A and/or B and/or C . . . and/or Z:

(A) Gages, calipers and other linear measuring instruments; (B) indicating instruments in general, including those for measuring variable magnitudes; (C) recording instruments; (D) testing machines and instruments; (E) inspection equipments; (F) optical and precision laboratory instruments; (G) telemetering systems; (H) prime-mover governors, furnace controls, etc.; (I) meters; (J) automatic controllers; (K) electric motor controllers and switchgear; (L) photoelectric and electron-tube devices; (M) valves, dampers, etc.; (N) clockworks, etc. (O, P, Q . . . . . Y, Z).

There is fairly good agreement, however, on the SCOPE of Instrumentation as originally tabulated about twenty years ago and published several times without change. Nearly four years having passed since the last printing, it is reproduced here for the information of the 6000 or 7000 new *Instruments* readers who did not see it. It has of course been amplified since first made up as you see it (the 1930 tabulation took three pages of *Instruments* and today's would fill ten) but its basic scheme endures.

Close to the atmosphere of *this* Conference, however, are two of the 39 definitions we had prepared for the 1942 AAAS Conference:

37. Instrumentation is the philosophy based on (a) the proposition that the conditions of human society and of industrial processes and operations—i.e., the "forces of Nature"—should be controlled; (b) the principle that before a condition can be controlled it must be measured; (c) the dictum that in order to measure a condition or property it must be segregated; (d) the slogan "If you control it manually you should control it automatically."

39. Instrumentation is the common interest, curiosity, fascination, inclination, enthusiasm, attraction, devotion, . . . etc., which binds us together.

—MFB

THE TWO ACTIONS TAKEN BY THE CONFERENCE BY UNANIMOUS VOTES

TELEGRAM

[Sent to Rep. McDonough, to all members of the House and Senate Military Affairs Committees and to all Pennsylvania Senators and Representatives.]

In view of the critical shortage of scientific personnel, it is the desire of the Conference now in session on Instrumentation and the University sponsored jointly by the Carnegie Institute of Technology and The Instrument Society of America, that favorable action be taken immediately on H.R. 2827 introduced by Congressman G. L. McDonough on April 2, 1945.—CONFERENCE ON INSTRUMENTATION AND THE UNIVERSITY.

DAY LETTER

[Sent to Dr. John Ward Studebaker, U. S. Commissioner of Education]

In the Conference on Instrumentation and the University, sponsored jointly by the Carnegie Institute of Technology and the Instrument Society of America, the need for industrial instruments for laboratory instruction was stressed. This conference was held at Carnegie Institute of Technology on October 16, 17 and 18 and was attended by educators from leading universities and schools of 17 states and the District of Columbia.

In the development of an educational program to meet the needs, brought out by the conference, for trained instrument personnel, it was apparent that laboratory training requires considerable quantities of individual instruments for which schools do not have sufficient funds.

It is considered that surplus instruments that may become available would be particularly useful for this program if they could be secured at a nominal price. In this manner the surplus instruments could be put to their maximum economic use.

A motion, unanimously passed by the conference, recommends that procedures be promptly established to provide for distribution of this surplus equipment to educational institutions.

A. L. SPERRY, *Instrument Society of America*
B. R. TEARE, JR., *Carnegie Institute of Technology*

KAYAN

SPERRY

DOHERTY

TEARE

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Tuesday afternoon session—W. L. McCABE, Head of Dep't of Chem. Engrg, C.I.T.
Wednesday morning session—DOUGLAS MINER, Ass't Dir., Engrg & Science, C.I.T.
(substituting for Professor SEITZ who was called to Washington)
Wednesday afternoon session—A. F. SPERRY, President, I.S.A.
Thursday morning session—E. M. WILLIAMS, Assoc. Prof. of Elec. Engrg, C.I.T.
Thursday afternoon session—P. G. EXLINE, Section Engr, Gulf Research & Dev't Co. (I.S.A.)

COMMITTEES APPOINTED DURING CONFERENCE

The Conference took action on two matters affecting legislation or decisions by Federal agencies. Each was decided by a unanimous vote; and in each case the Session Chairman appointed a committee to embody the desires of the Conference in a telegram to the appropriate officials in Washington. For texts of telegrams, see facing page.

1. *Deferment of scientific personnel* (appointed by Session Chairman Miner): *Chairman*, P. N. Powers, Naval Ordnance Laboratory; F. H. Pumphrey, General Electric Co.; R. J. S. Pigott, Gulf Research; R. Rimbach, Sec'y *pro tem* of I.S.A.

2. *Surplus Instruments* (appointed by Session Chairman Williams): *Chairman*, R. C. Darnell, Instrument Development Labs.; Ernest Capelle, former Chief of WPB Instrument Branch; S. R. Beitler, Ohio State University.

CONFERENCE DINNERS

Conference members met Tuesday and Wednesday evenings at informal dinners. No stenographer: the "Proceedings" live in our memories.

The University Club was the scene of the first; Carnegie Tech was "host" and Professor Teare was Toastmaster. President Doherty extended the official welcome and Professor Mehl spoke on his recent experiences in South America and Europe, showing lantern slides of scenes of interest to technical men, reporting on conditions, calling attention to elaborate plans for scientific research in Russia and other countries, and pleading for support of research here.

The Wednesday dinner was held at the Schenley Hotel; the I.S.A. was "host" and Secretary Rimbach Toastmaster. President Sperry gave a brief inspirational talk and the illustrated lecture was given by Dr. C. R. Hanna of Westinghouse Research, whose subject was "Gyro Stabilizers." These are the automatic controllers invented by Dr. Hanna, which enabled tank gunners in field tests to score 70% hits while racing across rough ground (1% without stabilizers), and correspondingly increasing our fire-power.

OFFICIAL ATTENDANCE RECORD, CONFERENCE ON INSTRUMENTATION AND THE UNIVERSITY OCTOBER 16, 17 & 18, 1945

(From registration cards.—An undetermined number of men and women attending one or more sessions did not register.)

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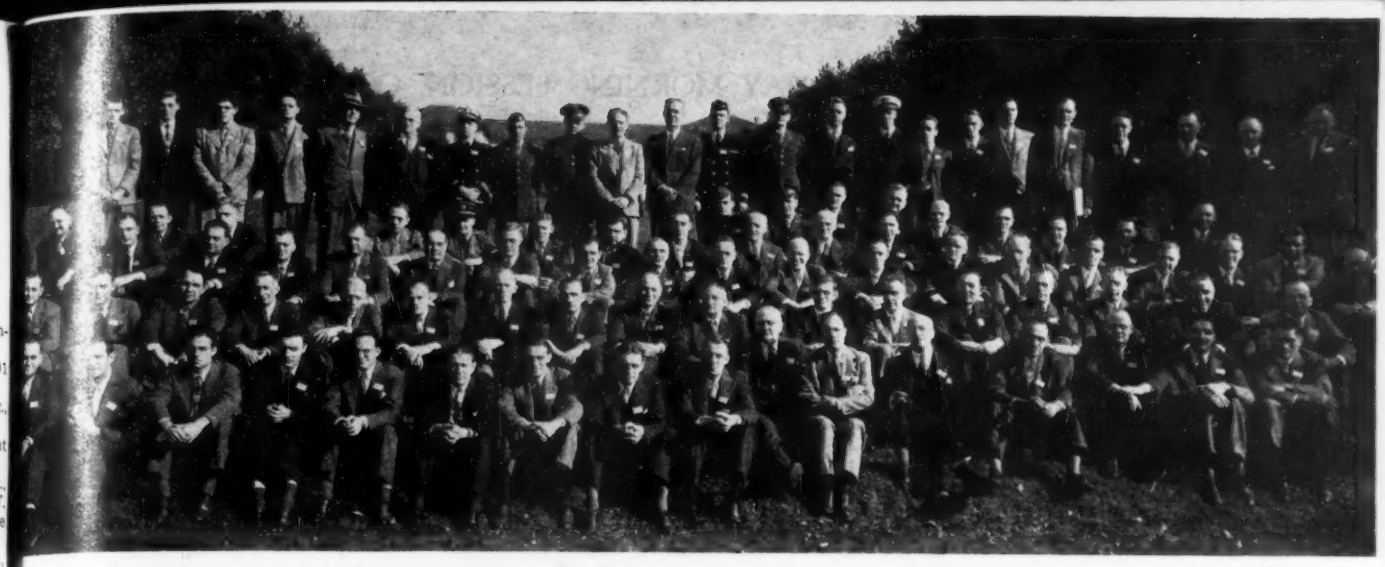

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Engineering Fundamentals or Specialties?

Opening Address, Conference on Instrumentation and the University

By B. R. TEARE, Head, Electrical Engineering Department, Carnegie Institute of Technology, Pittsburgh.

ON behalf of the Carnegie Institute of Technology and the Instrument Society of America I extend to you my heartiest welcome to this Conference. We are very happy to have you here to renew old friendships and to get acquainted with those of you who have not been here before. We trust that the program that has been arranged will come up to your highest expectations.

This Conference grew out of a series of discussions between members of the instrument society and of the faculty. Instrumentation, the science and technology of measurement and control, is of great importance and of very broad application. It underlies and pervades all the many ramifications of industry, more often cutting across the different branches of engineering and science than staying within conventional boundaries. Many of the manufacturers and users of instruments, and teachers as well, feel that more can and should be done in the colleges to prepare men for work in the field of Instrumentation. The question is, how may this best be accomplished? Educational improvements to the desired end might take the form either of new specialized courses, or of greater emphasis on fundamental principles together with more examples and applications drawn from Instrumentation. Either change implies that something else must be dropped from curricula that are already overcrowded. It may be that general agreement as to details of best procedure cannot be obtained, but at least a sound basis for making a choice will be provided by the discussions of this Conference.

The chief difference of opinion undoubtedly lies in the choice of educational purpose — whether general, fundamental principles should be taught together with considerable emphasis on how to apply them in new situations, or whether the instruction should be directed toward specific instruments and specific current procedures. The latter prepares a student to be more immediately useful to his employer but does little to prepare him for leadership in extending knowledge and practice, which is the goal of the former. On the other hand, if education is directed primarily to general principles, it is inevitable that the employer must complete the student's training with a program of post-college instruction.

The difference in point of view is not confined to education in Instrumentation: indeed, it is common to every aspect of engineering education. The trend appears to be in the direction of teaching the fundamentals more thoroughly with less time devoted to specific subjects and practices that are immediately useful. There are several reasons for this trend, chiefly:

(1) the fact that engineering at its highest level is more directly concerned with developing new apparatus, instruments and procedures than with dealing solely with old ones;

(2) engineering has expended to such breadth—consider Instrumentation for example — that it seems impossible to include much specialization in a student's program;

(3) students rarely are in a position to choose a narrow specialty and experience shows that even when they do, they often do not follow it.

Thus, from the point of view of general changes in education, it would seem that the field of Instrumentation would be served best not by trying to introduce specialized courses in particular phases of the subject but by placing greater emphasis throughout the program on the applications of general principles to Instrumentation problems, and by making the students more aware generally of the problems in the field. This might or might not require new courses.

The last few years, when attendance has been low, have been a period of intensive stock-taking and planning in the schools. Every institution has had its post-war planning committee; and interest in curriculum building is running at a new high level. Consequently, this is a most opportune time for our deliberations. The plans and decisions that we in the schools must make will be based in a large measure on the needs of industry, which is the ultimate consumer of our product: the engineering and science graduate. And we are looking forward to the chance of hearing these needs discussed so that we prepare an adequate product to meet them. Hence this Conference.

The organizing committee has brought together this group of responsible people representing instrument manufacturers, instrument users, the armed forces, and the universities, to discuss Instrumentation in relation to education. We feel it is appropriate to consider questions such as:

(1) What qualities and what abilities does industry expect of the graduate?

(2) How can the schools best develop these qualities and abilities?

(3) What specific changes should be made in undergraduate instruction? In post-graduate instruction?

(4) What is the present state of the art, and what are the trends?

(5) How can the schools adapt their programs of research to be most effective in Instrumentation?

(6) How can engineers and scientists in the field cooperate with each other to greatest mutual advantage?

During the next three days in which we are exchanging ideas, I am confident that we will find answers to these questions and to the many more that will present themselves. My associates and I will do everything in our power while you are here to make your stay most profitable, whether it is helping you find lodgings, or locating for you the man who can answer your questions, or, indeed, making you available to answer the other man's. May this meeting be so successful that in the future other meetings will be demanded, as this one was.

Instruments and Man

By R. W. GERARD, Professor of Physiology, University of Chicago, Vice President Chicago Technical Societies Council

I WONDER how often the men who plan or make or use instruments pause to consider the enormous significance for mankind of their "gadgets." For instruments and the men responsible for them are the sense organs of society, the eyes and ears and nose and skin wherewith human beings pry out the nature of the world about them. And the instruments and the machines they make possible are the doers, the muscles, of society with which man acts upon this world.

This is not the place, nor is there time, to develop the full argument that a society is a sort of organism, an epiorganism, standing in much the same relation to the individual men who constitute it as does a single man to his constituent cells.* But that this is so—and in a genuinely meaningful sense, rather than as a superficial analogy—is clear from many detailed biological facts. Living systems have shown a steady trend in evolution, from homogeneous cells (bacteria), through differentiated cell regions (paramecia), cell aggregates (some sea weeds), differentiated cell aggregates (slime molds), true multicellular organisms (man), organism aggregates (a locust swarm), differentiated organism aggregates (coral reefs, families), to true epiorganisms (beehives, deer herds, human societies).

From earliest to most recent epochs, there has been a directional drift to greater differentiation of parts in a whole and to combination of single wholes as units in a new and more inclusive whole. Man is more than amoeba because he is more elaborate in organization (as a radio network is to one crystal set) and because this organization enables him to react to more things in his environment and with greater precision, power, and variability. Similarly a city or a nation is more than a man or a collection of savages because it has a complex organization that makes it more sensitive to its surroundings, think of the network of weather observation stations, and more able to cope with them, think of Grand Coulee Dam or of the late lamented war effort.

Now all this evolutionary sweep depends on the pressure of the environment, of the world or universe in which living things live and reproduce. The surroundings present a succession of problems which the individual—and so the race—must solve: it must capture food, avoid danger, cover space, resist heat and cold and drying, establish its young. Each solution permits new behavior which encounters new problems. When solutions are not invented, the individual and race die out and other, more successful ones, survive. Surely it would be expected that a high premium is placed on sensitivity to one's surroundings; that animals with better vision, or smell, or touch, would get on better than their less sensitive relatives. And, in fact, it is clear from extensive studies that better and better sense organs appear along the evolutionary sequences. Moreover, it is equally clear that the better sense organs, machine-gunning the primitive nervous system with more, and more meaningful messages, are responsible in turn for its evolution into a brain. The world acts on living individuals, it leads to an evolution of sensitive receptors of stimuli which leads to a swelling brain, which makes possible (via better muscles) more complex behavior, which exposes the individual to new stimuli, which . . . and we are where we came in, but one floor higher on a spiral staircase. The sense organs are the catalysts, really the autocatalysts, of evolution.

And note that the sense organs of an animal are not all single cells or groups of living cells. They include non-living materials made and used by these cells. The fluids and the transparent lens and cornea of the eye—all its optic system except the photographic plate or retina in its depths—are practically composed of non-living protein fibers or gels. The membranes and fluids which vibrate to sound in the ear are similar non-living jellies or fibers. They are biological instruments!

The same applies to societies. The wax comb of honey is made not by one bee but by the group. So for the coral passages of lime, or the termites' nest of wood or mud. And so for man's houses and railroads and waterworks. The inanimate is incorporated into the function and activity of the living whole. Which brings us back to the material instruments of modern civilization and to the men who conceive and make and apply them. For these men—the scientists and technologists and their instruments—are the sense organs of society. They are the catalysts of social evolution. They make and remake man's world.

New ideas flow from new experience which, for the human race, comes from new instruments. Man's mind is not improving biologically; the geniuses of the past are not overshadowed by those of the present; but man's knowledge is greater because his bodily senses have been so extended by his instruments. As I have put it elsewhere:

> "Collective man is certainly sensible to vast territories of the universe beyond those accessible to the individual. Not only the microscope and telescope, which extend spatial vision to the minute and the colossal; and the spectroscope, which extends 'color' far beyond the visible spectrum; but also electronic instruments which create or detect radio waves, x-rays, radioactive rays and particles, cosmic rays—or for that matter, the simple compass needle which detects a magnetic field—all inform us of phenomena completely foreign to man's biological senses."

Instruments extend the range, the discrimination, the sensitivity, the precision of our senses. And each increment brings new facts, new experience, to our minds and stimulates them to new adventures, new ideas. As Sir James Jeans pointed out:

> "Just as Tycho's eight minutes of arc, in the hands of Kepler and Newton, revolutionized medieval conceptions of the universe, so Leverrier's 43 seconds of arc in the hands of Einstein, has revolutionized our nineteenth century conceptions . . . of the nature of time and space and the fundamental ideas of science."

Only better and better instruments enable man to deal with arcs by degrees, then by minutes, then by seconds.

And only science is truly cumulative and universal in human history. Art, religion, culture is individual or local in time and space. Shakespeare's writings did not enable his followers to write even better than he; ethical beliefs and moral practices are different for great groups of mankind and at different epochs for each group; visiting or eating or dressing is performed in accord with the shifting dictates of custom and fashion. But Newton could truly say, "If I saw farther 'twas because I stood on the shoulders of Titans." And Japanese as well as American guns fire in accord with the same laws of ballistics.

From instruments comes a steady barrage of new stimuli to the epiorganism, and from these there must eventuate, sooner or later, a better "brain" for society—more universal, more effective, more integrated social organs for making all humanity a global entity. What institutions will serve, how they are to be created and tested, cannot be predicted, but that they will come seems certain. I should think that the instrument men and their objective approach to problems will play a decisive rôle. I should think that scientists

Continued on page 846

Presented at the Conference on Instrumentation And The University, Carnegie Institute of Technology, Pittsburgh, October 16-18, 1945.

[Read by Mr. Sperry in the absence of Dr. Gerard.]

*See, for example: "Organism, Society and Science," *Scientific Monthly*, Vol. 50, 1940, pages 340-350, 403-412, 530-535. "Higher Levels of Integration," *Science*, Vol. 95, 1942, pages 309-313.

Human Engineering and Instruments

By Commander D. L. HIBBARD, Director Special Devices Div., Office of Research & Inventions, Navy Dep't, Washington

IN the past few years there has been a rapid development of ingenious instruments and, paralleling this development, there has been a commendable increase in the effective use of instruments. These products have been necessary because technology has advanced to a point beyond the ability of our human sensory systems to react. To control the vehicles and machines of the future, the trend will be to depend more on indications from instruments and less on the "feel" or "sound" of equipment in motion.

With the changes in technology, there should theoretically be concurrent modifications in the human body. Perhaps it is fortunate that Nature cannot be easily or quickly changed, for it would not take long for the engineers to make freaks out of human beings. Not only do we, as a people, abhor the idea of deforming the human body to satisfy objective conditions; but, as a nation, we have always preferred to redesign equipment rather than to select individuals for special functions. For instance, it would be easier to design racing cars, fighter planes or gun turrets for very small, light men, yet such selection concepts have been dismissed almost before they were considered.

In aircraft, for example, the cockpits have made allowance for substantial variations in the physical and mental differences in pilots. On the other hand, this war has produced only one really successful device in aircraft for modifying the man. The pilots' requirements of oxygen to breathe, goggles to relieve eye strain, instruments within view, controls within reach, protection from wind, etc.. were satisfied, but there seemed to be no effective solution to "blackout" when the body was subjected to severe and continued centrifugal forces. It was only as a last resort that the pressure suit was designed to change pressures in the human circulatory system: By modifying the man, the objective was accomplished. Although this is an interesting approach, it seems advisable to devote our energies, for the present, to helping "man as he is." Perhaps some other nation will prefer to produce a super pilot by making him eagle-eyed with drops in his eyes, keep him alert with drugs, give him courage with dope, ease his pain by sedatives, etc. To the engineers of this country the challenge is to attain the same ultimate objectives by designing equipment around the man who is to use it.

The interest of engineers in the field of instrumentation appears to have been essentially that of solving a problem in such a way that it would be appreciated by other engineers. Unfortunately, this is only a partial solution, as a few examples will indicate:

(1) Many engineers are surprised to learn that a pilot is not interested in the actual cylinder head temperature of his engine—frankly, he doesn't care Centigrade or Fahrenheit — he only whether it is 100°, 200°, or 900°, either wants to know whether it is reasonable;

(2) If one were to ask automobile drivers what oil pressure is correct for their car engines, it would be quickly realized that the instrument is made to satisfy an engineer—a good instrument and an excellent job of calibration perhaps—but certainly the gage was not "designed for use" by the average driver. If a car will run undamaged for five minutes at high speed without any oil pressure, the engineers have tacitly made the assumption that every human driver will check his oil pressure gage at least once every five minutes while driving—a rather fanciful assumption;

(3) The present ammeters on most cars are often a source of unnecessary worry. In the old days the ammeter would usually indicate that the generator was charging the battery at a reasonable rate and one could turn on the lights to reduce that rate when he wanted to show his technical prowess. Now, however, this excellent instrument registers zero most of the time. To say the least, such an indication is of no value—either psychological or technical. Why not put the instrument under the hood so as to prevent worrying the befuddled occupants of the car?

An examination of the instrumentation in ships, on submarines, in railroads, in buses, in planes and even in industrial power and heating plants often shows an imposing array of beautiful and accurate equipment, with the human engineering aspects almost invariably ignored. It would be interesting to study examples of these types of instrumentation, but it will only be possible to select one type for brief discussion today. The remainder of this paper will be devoted to a discussion of instrumentation in aircraft from the human engineering viewpoint.

Instrumentation in aircraft can be divided into three parts—flight, power, and navigation. To fly an aircraft under instrument conditions requires not only a considerable amount of training, but also continual "refresher" training. Few pilots are willing to fly on instruments if they have gone as much as six weeks without some "practice." This is necessary, not because the pilot forgets how to fly, but because of what he has to do when "on instruments"—a process so unnatural that he has difficulty remembering it with confidence. The problem is primarily a psychological one but, if it exists and if most pilots have such trouble, then it is up to the engineers to change the prescribed requirements. Actually, instrument flying today consists of a mechanical procedure in which the pilot attempts to neutralize or match pointers so as to produce normal straight flight. Deviations from this neutral position require quick thinking, a correlation of various instrument readings and a decision as to the appropriate action required. These judgments may appear simple to an engineer on the ground, but imagine the conditions under which the instruments are really used. The pilot "on instruments" is being bounced and jerked in the rough air; his radio is probably useless because of static; the carburetor temperature shows that icing is likely; the fuel gage (which is never quite accurate) is moving toward empty; the compass is indicating every direction equally; the incessant droning of motors is in his ears superposed on the static; the instrument lights cause short hypnotic spells which he must resist; the wind is blowing him off course; and he isn't sure where he is. Yes, these are the conditions under which instruments require that he keep thinking, deciding, and correcting—thinking, deciding, and correcting, methodically and without error for hours on end. Unfortunately, the frailty of man is such that he cannot stand such strain for long.

The pilot always prefers "contact" flight, for this is far easier for him than instrument flying. Contact flight is not accomplished simply by sensitizing the seat of a pilot's pants. Actually many of his so-called natural reactions in the air are based on a composite view of his surroundings. The pilot does not necessarily use the horizon line as a reference for he often uses peculiar conditions in the surrounding terrain with considerable emphasis on the foreground. Thus, in turning and banking an airplane on contact flight, the pilot estimates a balanced condition of the visible horizontal surface while watching a mass movement of this surface under the aircraft. When such factors are eliminated, there is a strain to fly and therefore it is profitable to engineer, if possible, an instrument which simulates the conditions of effortless flight. Such instruments are now under development and some have passed the initial tests very satisfactorily. If one were to forecast the optimum type of instrument on the basis of known technological developments, a fog-cutting television device would be selected: a device which would not only permit safe flight at altitudes, but also make possible blind take-offs and landings with reasonably normal contact indications. From a human engineering viewpoint, this simulated flight instrument

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Presented at the Conference on Instrumentation And The University, Carnegie Institute of Technology, Pittsburgh, October 16-18, 1945.

For DISCUSSION of this paper see pages 808-812.

POWERS HIBBARD CALLAHAN WILDHACK

SOME OF THE SPEAKERS FROM THE ARMED FORCES AND FEDERAL GOVERNMENT BUREAUS

should have combined with it, insofar as the usual presentation is concerned, a non-tumbling, stabilized magnetic compass.

The eye-strain and vertigo caused by the continual refocusing of the eyes first on distant objects of one brightness and then on the delicate instruments in another brightness pattern must be eliminated. It is easy enough to say that when a pilot is flying on instruments he should not try to look out. Unfortunately, we cannot change the nature of others by an act of will, and under trying conditions I have found myself looking intently into cloud and fog when I knew it was both hopeless and foolish. A man wants to look where he is going, and apparently one cannot kill this desire and his optimism in even one short generation. If this is the case, then arrangements should be made so that a pilot can look at his instruments while looking ahead. This was done with the optical gun sight and can be accomplished with the more important instruments. To minimize eye-strain it will be necessary to project the optical views of the instruments to infinity so that the eyes will not need to readjust. Preliminary tests indicate that these images can probably be reflected from a large wind screen.

As an example of poor human engineering on an aircraft instrument, one need only point to some of the present altimeters. As the altitude of aircraft has increased, the instrument has not been redesigned to provide a simple presentation, but instead it has been complicated by the addition of two more hands, so that one hand in one revolution indicates 1,000 feet, another indicates up to 10,000 and the third takes it on up. With three hands on one instrument dial it is virtually impossible for an ordinary man to glance at it and know his altitude—frankly, even the intelligent experienced pilot fails. With the new high-speed aircraft which in military operations may dive from 20,000 to 2,000 feet in a matter of seconds, it is necessary to have an instrument which can be read easily. Research should be done in the design of an altimeter having on its face an open window in which altitudes can be presented directly in figures. Certainly in future operations it will be necessary to know one's altitude with even greater precision than at present.

The present vertical-speed or rate-of-climb indicators are highly sensitive, but cannot be read accurately except under extremely smooth air conditions. Since the value of this indicator is its indication of a percentage of descent or climb, it would be beneficial if this indication could be combined with the altimeter by an additional sweep hand. This would not only simplify let-down procedure, but it would also eliminate one instrument from the panel. From a use viewpoint, such a combination is desirable.

The present air-speed indicator tries to calibrate air speeds from 0 to 800 knots in a single revolution on a 2¾" diameter dial. Speed changes of less than five knots cannot be determined by the pilot under flight conditions. Since speeds will be even greater, it is probable that the open window type of instrument, similar to the suggested altimeter, will be required for ease and accuracy of reading.

When the flight problem is reduced to an air-speed indicator, an attitude indicator and an altimeter designed along human engineering lines, the time for indoctrinal training in instrument flight can be greatly reduced, and the time required for refresher work will no longer be a problem.

The method of indication of power instruments in present aircraft is highly complex. The average aircraft's power instruments consist of a minimum of eight to ten different indications which are considered necessary to enable the pilot to determine engine condition. Each dial has a different type of calibration, requiring a shift in the pilot's thinking from one type to the other. Some are large-size instruments whereas others are small. The location has been fairly well established, but there is still a lack of complete grouping.

Pilots have been asked how they determine whether their engine is functioning properly and how their power instruments give this indication to them. The consensus among pilots is that they do not rely on the amount of indication but rather on the *position* of the indicating needle. The amount of indication varies with various types of aircraft. For example: Fuel pressure in most aircraft amounts to approximately four pounds, whereas, in fighter types, the fuel pressure may run around eighteen pounds. When a pilot who has been accustomed to reading four pounds suddenly finds himself looking into an instrument giving an indication which is four times larger, he is disconcerted.

It is interesting to note the indications for the various power plant instruments that must be read and mentally calculated by the pilot. The units as well as calibration vary with each instrument. Here are examples: An oil gage reads from 60 to 90 *pounds;* the manifold during normal cruising reads approximately from 25 to 30 *inches;* the tachometer reads from 1900 to 2900 *r.p.m.;* cylinder-head temperature will be roughly in the neighborhood of 150° *Centigrade.* It is apparent that there is little similarity between the various instruments, yet each one should be read correctly to assure the pilot that the engine is functioning properly.

One step which has been made toward the simplification of power plant instrument reading is the addition of red and green arcs which are painted on the dial glass of the individual instruments. This permits the pilot to determine rapidly whether the indicator needle is either in the red or green sector—red indicating a maximum limitation, and green indicating a normal safe condition. This method, however, does not eliminate the complex mass of varying indications which register in the pilot's eye. It does not eliminate the necessity for the pilot to segregate one instrument from the other. It is not uncommon for a pilot to read the tachometer indication for manifold pressure and vice versa, nor is it uncommon for a pilot under strain to find himself steering his cylinder-head temperature as a course indication if those figures closely approximate his compass reading! With the advent of supersonic aircraft, calculations of this type must be made in split seconds—which will be impossible unless some change is made in present types of indication.

Certain commercial airlines at one time adjusted all instruments on the instrument panel in such a manner that when the aircraft was cruising, all needles would align themselves either horizontally or vertically. This, as well as the addition of the red and green arcs, is a definite indication that pilots are asking for *a pattern indication rather than a quantitative figure.* Research should be done in the development of a straight-line instrument which would combine all the various power-plant conditions into one unit.

KAYAN

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MILLER

BEITLER

SOME OF THE SPEAKERS FROM UNIVERSITY SCIENCE AND ENGINEERING DEPARTMENTS

In this type of instrument, the range of indication would be over a series of conditions rather than a designated amount. If such an instrument were available, then any pilot could determine the condition of his engine at a glance, for a reasonably straight line would indicate that his engine was functioning properly whereas a hump in that line would show that a faulty condition existed.

Certain simplifications could be made by eliminating instruments from the panel and by replacing them with indicator warning lights. Instruments such as oil-pressure, fuel-pressure or carburetor-temperature indicate only a condition and cannot be corrected by the pilot: they are merely a means of warning him if his engine is not functioning properly. Although it may not be practical to eliminate these instruments from the aircraft since the mechanic may need them in order to check his engine thoroughly before flight, it may be advisable to remove them from the instrument panel and place them in another position in the aircraft so as to relieve the pilot of viewing any indications other than those absolutely necessary to his flight.

Still further simplifications in this group can be achieved by making certain conditions fully automatic. In the case of the cylinder-head temperature, for instance: this condition can be corrected by the operation of cowl flaps or the adjustment of throttle or mixture control. This action can be thermostatically controlled and will eliminate the need of an instrument for the pilot's use. Such corrections constitute the simplest forms of human engineering.

In addition to the flight problem and the power problem, it is necessary for the pilot to navigate his plane for long distances under varying conditions. A great many aids have been given to the pilot to simplify this problem, such as radar, YG, Loran, and of course the standard radio range. All of these still require considerable thinking and mental calculation on the part of the pilot, as well as extensive training. Navigation is in a sense a mathematical problem, and it is believed that the development of an automatic computer for navigation is necessary. If the problems of navigation can be eliminated from the pilot's mind, he can then concentrate on the main objective of his mission. There is ample reason for the worry caused the carrier pilot by the navigational problem. Pilots in the North Atlantic have experienced severe changes in wind directions four times in one hour and, on bad days, a pilot who was not alert to such changes would never see his carrier again. Imagine the problem of a pilot who flies almost to maximum range before he is engaged in a dog fight for twenty minutes, and then, still over water, must guess where he is and navigate back to a platform which has moved many miles from where it was left! No one can go on such a mission without wishing he had a robot navigator with him.

The introduction of pressure pattern flying has opened up the possibility of obtaining automatic wind drift when flying over water. It is probable that the use of radar or high-frequency radio can be used to obtain drift when over land masses also. If this can be accomplished by the use of a computing mechanism and then correctly presented to the pilot on a map or chart, the navigation problem becomes fully automatic. Human limitations preclude a satisfactory solution with the use of the present instruments.

With the development of rotary-wing aircraft, proper navigational instrumentation is an absolute necessity. So far as is known, there is no instrument developed to date which will determine the direction in which the helicopter is moving. Some means of determining relative motion in the air must be found, for it is beyond the ability of man to obtain a solution from present instruments.

Simple solutions for determining the angle of attack, line of thrust, gross weight calculation, and other aerodynamic characteristics are now needed and all of these developments will be necessarily prolonged if there is not an immediate recognition of the physiological and psychological problem involved in human engineering.

The instrument engineer is now caught in the current passion for visual indications. On every hand one hears that 90% of the information received by individuals in this day and age comes through the eyes. There are promotional campaigns in visual education and training which tend to corroborate this belief. It might be well to stop for a moment and consider the fact that, at least in instrumentation, *it is not necessary to overburden the eyes still more.* The current use of sight by aircraft personnel is reaching such a point that a sudden lights-out situation may be fatal. (In this war good pilots are known to have been lost because of failure of instrument lights for a few seconds). Very little has been done in regard to flying a plane by means of the auditory sense, although such prototype equipment has been produced and successful flights have been made with the pilot blindfolded. The ear is in many respects as sensitive as the eye. It can listen to at least five sound impressions simultaneously; it is possible to ignore what is not wanted as in sight: it is possible to fly as straight blindfolded as with a full view of the instruments. All this and much more is already possible and such considerations should be included in any study of human engineering applied to instruments. It must be remembered that instrumentation must act *through* the optical and aural instruments of the human machine since, at present, there is no short-cut to the brain. Even so, there is still almost an infinite variety of ways of presenting information in such a way as to produce a reaction from man. It is a responsibility of the engineer to recognize these factors and to use them when the need arises.

The design of an instrument should include consideration of such human factors as the time of reaction, the tendency toward errors when tired, the difficulty of solving even simple problems when under mental and physical strains, the effects of color, the determination of factors which will make the brain conscious of an indicated condition, the limited number of stimuli to which a sensory organ will respond, the unnecessary overloading of one sense organ such as sight, the apparently overpowering desire of man to look where he is going, night vision, appreciation of human errors in averaging such oscillating motions as occur in certain instruments, and the effect of quick repeated changes in focusing the eyes. All of these and many more are of real importance in the field of instrumentation. Engineers must do more than provide an accurate, consistent instrument—they must design it for use. The engineer must have the interest to ask not only for specifications as to size, weight, function and accuracy but also obtain information on such mat-

ters as where the instrument is to be placed, who is to use it, how often it is to be consulted, under what lighting conditions it will be read, and how the information is to be used.

Just as an engineering course instructs one to treat all variables in a problem with a reasonably equal degree of accuracy, so an engineer should be taught to design instruments which correspond to the accuracy of the human elements which are concerned. The neglect of comparatively simple elements in human engineering has cost millions of dollars in training and efficiency as well as the lives of many military personnel. It is essential to peacetime efficiency that present errors be corrected and that new ones be minimized. One way to make sure that these factors are considered in the future is to ingrain such thinking in the minds of the embryo engineer. Therefore, it is strongly recommended that the education of an instrument engineer include (1) a study of the human factors involved in the use of instruments and (2) a consideration of the effective arrangement and coördination of instruments.

Future Requirements for Instrumentation in Aviation

By Major J. G. P. CALLAHAN, Chief, Instrument and Navigation Branch, ATSC, Wright Field, Ohio

ON 15 August 1945 Aviation entered a new era. Commercial transports are now encircling the globe with plans visualizing several complete bands of regularly-scheduled routes. The further development of commercial air transport will make use of higher altitudes, higher speeds, supercharged cabins and jet engines. Private aircraft of the fixed-wing variety have a handicap out in front of rotary wings. Helicopters should find their field in the next five years conquering their present obstacles of vibration and complicated control systems. Design conceptions of military aircraft are now leading "Buck Rogers" and "Superman" by a nose whereas on 7 December 1941 they trailed by fifteen years.

Today, in the aviation field, aircraft instruments "made in the United States" set the standards for the rest of the world in quality of workmanship and reliability of performance under all flight and climatic conditions. To the Army Air Forces must be given much of the credit for this situation. The research and development program which was initiated after World War I by the United States Army Air Corps was sustained and wisely administered at Wright Field during the years of peace. One bit of evidence to substantiate this credit is found in the fact that before World War II life insurance rates quoted to Air Corps Pilots and crew members by the National Aviation Insurance Underwriters were lower than those quoted to Airline Pilots and Private Pilots. One of the prominent reasons which the underwriters gave for this policy was that flight and navigation instruments installed in aircraft of the Air Corps were of better quality and more reliable than the equipment used in commercial and private aircraft.

Throughout the war, our allies have been glad to obtain instruments which have been "made in U.S.A." Careful examination and study in this country of our allies' products and of captured enemy equipment at Wright Field, and at contractors' plants have disclosed many new ideas and techniques. They have also brought to light a surprisingly large number of direct copies of American designs of instruments and navigation equipment. Each of these is a compliment to the young American aircraft instrument industry.

Henry Ford once said that if he knew what the car of the future would be, he would not merely describe it—he would build it. Prognostications always have limitations. Sometimes they have already been accomplished in the laboratory and merely await application engineering preliminary to production. Other times they are dreams of desirable solutions to problems. The dreams are oftentimes hazy as to means available to implement the solution. However, many dreamers from Leonardo Da Vinci to Jules Verne to the author of "Buck Rogers" have been vindicated by subsequent events. The future requirements for instrumentation in the aviation field which I am listing are comprised of dreams as well as problems for research and for development. I hope I can be vindicated half as well as Da Vinci or Verne have been. Here they are:

1. The measurement and indication of true airspeed of aircraft from 0 to 1000 miles per hour and of missiles up to 4000 miles per hour.

2. The measurement and indication of true height of aircraft above the sea level datum up to 80,000 feet and of missiles up to 80 miles.

3. Means for measuring free air temperature in aircraft.

4. Light-weight, accurate and reliable recorders of barometric pressure, free air temperature, and moisture content of the atmosphere for weather reconnaisance aircraft.

5. Means for insulating equipment from vibrations with frequencies from 500 to 10,000 cycles per minute and amplitudes up to 0.060 inch, as well as instruments for measuring and recording vibration characteristics.

6. A method for the determination and indication of the vertical in maneuvering aircraft.

7. Automatic drift indication.

8. A method of establishing a celestial navigation fix in aircraft using single observations.

9. A dead reckoning ground position indicator to operate in aircraft in all conditions of visibility without radio or other contact with the ground at the speeds and altitudes previously mentioned.

10. A celestial ground position indicator for use in aircraft during day and night with an accuracy of ± 3 miles.

11. Methods of polar navigation.

12. Methods of life raft navigation.

13. An automatic indication of balance of loaded aircraft.

14. A lubricant for gyro instruments, watches and instruments, suitable for use within the temperature range from $-85°$F. to $+200°$F.

15. A simple means of alloying steel for structural use in aircraft and missiles to reduce magnetic permeability and therefore reduce effect on magnetic compass elements.

16. More definite information concerning the orientation and strength of the earth's magnetic field at altitudes up to 80,000 feet.

17. A simple remotely-indicating system for engine r.p.m., pressure, and temperature functions in aircraft.

18. A system for measurement of fuel and oil quantity in aircraft and of rate of fuel flow. Long-range flights require accurate indications of the quantity of fuel available at all times, and particularly as that quantity becomes small.

Many universities in the United States have been concerned only with basic research in the realm of physics, chemistry and engineering. During World War II the Office of Scientific Research and Development turned the universities into many new paths of application engineering and practical design which were not charted on the conventional maps of the curriculum. The universities responded with enthusiasm and turned in many excellent performances including the Atomic Bomb and Radar. This wartime job should be the fountainhead of a trend in the university plan which will benefit our great country, our schools, our industry and our students during the years of peace to which we are all looking forward.

Presented at the Conference on Instrumentation And The University, Carnegie Institute of Technology, Pittsburgh, October 16-18, 1945.

For DISCUSSION of this paper see pages 808-812.

The New Importance of Those Who Use Instruments

By PHILIP N. POWERS, Naval Ordnance Laboratory, Navy Yard, Washington, D. C.

IN this paper I am not considering instrumentation problems as such. Instead, I am calling attention to a serious problem which has been forced upon you and me—the *users* of instruments—and one which is of vital importance to the nation as a whole.

This country is in danger of losing a battle which is being fought now. It is the battle for supremacy in scientific and technical personnel resources. There is no question about whether this battle is being fought. Reports coming in from abroad indicate clearly that other countries not only realize the importance of this basic resource but are bending every effort to train large numbers of scientists, to enhance their prestige, and to provide rich rewards in other ways for those who enter the scientific and technical professions. That is why we are in danger of losing this battle—and the consequence of losing it may be very serious.

We had world-wide superiority in this resource before the war began. Our weapons were far inferior in quality and quantity to those of our enemies. Nevertheless, we won the war. It was not because we had more rubber, or more oil, or coal, or steel, or even because we had more uranium. It was because we had more and better trained scientists—your colleagues and mine. With this resource we could make rubber and planes and ships . . . and atomic bombs. And we could do it faster than the Germans or Japs could.

We hope that there are not going to be any more wars and we will make every effort to prevent one. This country has already decided that the best way to prevent another war is to be strong. Therefore we must not lose this battle for supremacy in science. For war, or for peace, it is of the utmost importance that we maintain our leadership.

The importance of programs for scientific research and development as a basis for both military preparedness *and* peace-time prosperity is becoming generally recognized. The report of Dr. Vannevar Bush to the President and the five bills for the promotion of science now before Congress offer some evidence of this fact. These bills propose the establishment of some sort of Foundation with broad powers to grant funds, and otherwise encourage and coördinate scientific research in this country. The future of scientific research in this country therefore looks promising except for one fact—too little attention is being given to the development of the *basic resource* of *scientific* and *technical* personnel.

To be sure, these bills before Congress also propose that some fellowships and scholarships be granted. To be sure, there has been a considerable amount of space in our editorial columns devoted to the urgent need for the development of scientific talent. To be sure, the colleges and universities are ready and willing to train more scientists. To be sure, industry is going to offer many attractive positions which will encourage competent young men and women to enter into the scientific and technical professions. But all of this is not enough.

Our universities are unable to get graduate students in science. A large proportion of those who would be getting Master's and Doctor's degrees if they could are in military service. Some of us thought this situation would end with the war. It has not ended. Our young scientists were taken away from school and then they were the last to be drafted. They will be the last to get out . . . and they are still being drafted.

As a nation we have taken the smug position that our superiority in this resource has been so great that we need have no fear of another nation catching up with us. We have been drawing and are continuing to draw upon the reserves we possessed before the war began as if that reserve were limitless. Other countries know that it is not limitless. They see the opportunity to gain the advantage, and they are making every effort to do so. Offering a few scholarships and fellowships is not a big enough program to win this battle.

If we lose this battle, it doesn't matter how much money is poured into laboratories and research institutions: we will have lost the advantage and we may have no opportunity to regain it such as that which we are now offering to others. This would be the prime example of the familiar "too-little-and-too-late" policies. As you and I well know, training programs cannot be hurried in the same reckless fashion that a research or production project can be hurried by concentrating masses of personnel and facilities on the problem.

That is precisely what you *can* do if you have plenty of personnel available. It takes time to train people but, with superiority in personnel, you can if you wish step ahead of the enemy at any time in making weapons; you can develop new weapons rendering old weapons obsolete faster than he can. That is what happened in this war. The shift in military superiority from Germany to the United States and, in particular, the development of the atom bomb in this country provided evidence of the advantage possessed by us in the quantity and quality of our scientific personnel. And the same factor will continue to operate wherever two opposing forces appear. It is essential that we see to it that we maintain that advantage.

Well, what can you and I do about it? We were the ones who developed that resource in the first place. We are now the ones who employ what is left of that resource. Except for the few graduate students who have been released from the services, or are over twenty-six, or are 4F's, the remainder of that resource is employed on the staffs of educational, industrial or government institutions — *all represented here.* It is up to you and to me to carry on the development of that resource in such a way as to win our battle for supremacy in scientific personnel.

This is what we can do.

First, we can provide the group which is left in industry and in government with every possible opportunity for further training. This is a program which can be made effective at once: it does not have to wait for the appearance of new scientific talent.

The second thing that we can do is to organize a program to attract able young men and women into the scientific professions. This program should include not only the granting of fellowships and scholarships, but also the establishment of public relations which will increase the prestige of the scientific professions and which will result in the members of those professions receiving rewards which are more in keeping with the contribution they make to the national welfare and to national defense. As stated in Report No. 5 from the Subcommittee on War Mobilization to the Senate Military Affairs Committee on July 23, 1945: "In relation to their contributions to society, scientific and technical workers in and out of Government are probably the most under-rewarded group in our economy."

Programs which are designed to make scientific careers more attractive cannot become really effective until the potential scientists begin to come out of the armed services in larger numbers so that the universities can get a chance to go to work on the job of training them.

The training opportunities which we can offer to the group now employed in industry and government are of two types. First, and foremost, we can offer them assistance and encouragement in continuing their own academic careers. We can do this by inviting the coöperation of universities which are conveniently located with respect to our government and industrial laboratories. The desirability of such coöperative relations scarcely needs mentioning at this Conference which is already dedicated through its very title to the promotion of such relations. Arrangements could be made for university staff members to come to these laboratories to provide expert advice on laying out courses of study. Certain academic courses could be taught at the labora-

Presented at the Conference on Instrumentation And The University, Carnegie Institute of Technology, Pittsburgh, October 16-18, 1945.

For DISCUSSION of this paper see pages 808-812.

tory. They might even be partly or wholly on company time. There are many persons who are unable to get to university campuses who would jump at the chance to take these courses.

On the other hand, liberal leave policies or student exchange procedures can be established which do make it possible for employees to get to university campuses. Students might go for so many hours during the week, or they might go for so many months out of the year. Also, theses and dissertations may frequently be done through coöperative programs. In many instances the regular work of the employee is thesis material. One or the other of the coöperating institutions may have superior facilities for research in a given field. If the university is best equipped, the work might be done there, or vice versa. In either case, the employee is receiving further training and is progressing toward an advanced degree, and the interests of both institutions are being promoted.

These ideas are not new. In this city Westinghouse has had relations of this sort with universities for some time and now it is a standard practice of a number of other industrial institutions throughout the country. Although it is fairly rare in government, a number of doctoral theses have been prepared at the National Bureau of Standards; the TVA operated a student exchange program successfully for a number of years before the war; we have a coöperative program at the Naval Ordnance Laboratory; and there are other examples.

Most of these coöperative efforts in industry and in government have been limited to the graduate and undergraduate levels. To be sure, this is where the biggest problem lies. But on the other hand, we have somehow been propagandized to believe that once a man has a graduate degree he is fully trained. This is a fallacy. He may be well qualified to do a certain job consistent with the specialized training he has received; but it is tragically easy for him to get into a sort of rut. Unless he goes out of his way to attend the meetings of professional societies, to read widely, and to maintain other contacts with persons in his profession, he may quickly drop behind in his own field of specialization and certainly fail to enlarge his horizons into related areas. The security associated with Civil Service positions makes government scientists particularly likely to get into a rut. The higher rewards and the continuous competition make it less likely in industry. The men who are most in demand are of course those who, on their own initiative, won't allow themselves to get into any sort of rut.

There are ways, however, in which scientific personnel can be given assistance and encouragement in keeping ahead in their professions. That brings us to the second type of training which we can now offer to this group of scientists who are employed by industry and government. It is generally referred to as in-service training and, except for the various programs related to the indoctrination of new personnel, is found only rarely for scientific personnel. It may consist of scheduled courses and seminars in which latest developments relating to the technical problems of the laboratory are brought up for discussion. Experts in the field who at the same time are facile in the art of speaking and leading discussions can be made available for these meetings. If they are competently managed, those participating will gain a new perspective in their work, exchange ideas and stimulate further study and the development of new ideas. These courses and seminars may be at different levels. Trends and innovations relating to the over-all work of the laboratory may be the subject of a series of seminars attended by the more mature scientists. Special seminars on instrumentation may be arranged for those whose responsibility it is to design instruments. Special courses may be organized relating to the subject-matter of peculiar interest to the organization. And there are other possibilities.

We have considered thus far a program for the development of our scientific personnel resources which has both immediate and long-range effectiveness. We may also consider the other program which looks forward to the time when new scientific talent may become available in large numbers. The purpose of this program is to make the scientific professions attractive to all young men and women who will be choosing careers. The need for scholarships and fellowships to assist some of them in getting started is obvious and it is to be hoped that many will be available. In addition, however, the prestige of the scientific professions must be enhanced. Scientists must accept more public recognition of their services. You and I must receive more attention and be better understood by those who are not scientists. The day of the "long-haired" scientist is, for better or worse, passing. We have a responsibility to enter more into public affairs and to take leadership in the winning of this battle for supremacy in scientific personnel.

We may possibly take a lesson from Russia in this respect. She used an anniversary of the Academy of Sciences as an occasion to invite scientists from all over the world. Julian Huxley later described it in the July 30 issue of *The New Republic* as follows:

> Let us suppose a parallel event in Britain —that the Royal Society, immediately after the Japanese war ends, were to organize a fortnight's celebration to which foreign delegates from all over the world, as well as large numbers of scientists from the mother country, the dominions and the colonies, were invited. Then, to make the parallel with our experience, the Royal Society would provide free transport and free hotel accommodation for its foreign guests, would give an enormous dinner in the Savoy or Grosvenor House, would take Covent Garden for a night of opera and the Albert Hall for a special concert, would arrange for several special trains, all of sleepers, to take the party to Edinburgh—where the city would provide another banquet—and would, with its guests, be entertained at the Guildhall by the British government, the Prime Minister, the Foreign Secretary and other Cabinet Ministers attending in person. Furthermore, all the papers—*Times, Manchester Guardian, Daily Herald, Mirror* and all the rest—would feature the celebrations, and the achievements of science, especially British science, as front-page news, often the main front-page news, for two weeks.
>
> A man at the Australian Legation in Moscow told me that he had asked the servants there who was president of the Academy, and they all knew. I wonder whether even five percent of the people of Britain could name the president of our Royal Society, or five percent of Americans could say who was the head of the National Academy of Science?

How far we want to go in staging such demonstrations and in attracting such public attention is a question which we are forced to face. A society such as this Instrument Society of America must take a position on this matter. If we wish such attention, our national societies can take leadership in getting it. If we wish to avoid such attention, we must still face the competition of a group which is receiving such attention, and we must have a program for meeting that competition.

In conclusion I should like to describe briefly the efforts which we have made at the Naval Ordnance Laboratory to develop our own scientific personnel. We have found that one of the chief factors in attracting and keeping our younger scientists has been the coöperative program which we have established with local universities. Advice in academic matters and a variety of graduate courses have been made conveniently available. We have worked out procedures by which persons take leave for various amounts of time and we have arranged for theses to be prepared on the job in certain instances.

One of our most successful training ventures has been a weekly series of "Instrumentation Seminars." Those with special instrumentation problems discuss them with others concerned with similar problems. There have been many instances where this exchange of information has avoided duplication of effort and the development of better instruments. There are usually thirty to thirty-five persons in attendance, with different persons coming each week depending on the particular topic being discussed.

We have also had a series of ordnance seminars attended for the most part by top supervisory personnel. These meet twice a week, with each meeting repeated once in order that there shall not be too many supervisors away from their jobs at the same time. We have discussed latest developments in mines, in torpedoes and in other general problems relating to the sinking of enemy shipping. These problems relate of course to some of the over-all missions of the laboratory. The attendance at these meetings during the last year is eloquent testimony to their value. With the shortage of manpower and the high priority of our projects, these had to

pay off, or they could not have survived.

We have also had a series of short courses on the intricacies of present-day mines, torpedoes, and depth charges. These were attended by personnel who were designing and testing various components of these weapons, but who had no other opportunity to gain some perspective into the character of the weapon in which their particular components must go. As a result they avoided many errors that they could not have foreseen without this increased perspective and at the same time increased their professional stature within the laboratory.

We also had an elaborate course meeting daily for a period of nearly four months in which the body of subject-matter relating to the design of underwater weapons which has been discovered by our laboratory during the war was summarized and presented in a coherent and organized fashion. This course was equally successful.

We also arrange regular showings of selected training films to particular groups in the laboratory who are in a position to benefit from them.

Finally, we have organized what we call a Physics Club of N.O.L. It meets weekly immediately after working hours, and is intended to bring physicists from our laboratories into contact with physicists from other activities. The subjects discussed are selected by the speakers and have ranged over a wide variety of different fields in physics. Again, the continuous attendance over many months is evidence of the service which it performs.

Our training program is only a year old and we have made nothing more than a substantial beginning, but this program has already attracted wide attention and support throughout the Laboratory. We are making employment at our Laboratory more attractive; we are promoting the over-all efficiency and success of our technical work and, above all, we are developing those technical personnel resources for which we are responsible.

The Future of Measurement Control

By Major RUSH A. BOWMAN, Ordnance Department, U. S. Army

IN 1812 Eli Whitney undertook a government contract for the manufacture of muskets at an unprecedented low figure. Instead of the anticipated loss he enjoyed startling success. He performed the unprecedented, delivering the muskets in parts. This innovation was the result of the application of interchangeability in the manufacturing process.

It is a far cry from one thousand muskets made in one plant in the War of 1812 to the production which made the winning of World War II possible—involving the assembling of millions of items manufactured in thousands of plants throughout the country. But the answer is still the same: interchangeability.

The source of interchangeability is measurement control.

Measurement control is built on two basic skills—direct measurement technique and the application of the principles of selective sampling. Until the last decade these skills were hardly more than alluded to in the Engineering Curriculum, but industry during the war learned the dollars-and-cents value of a good product—right the first time. It will demand these skills among the skills it buys in the post-war period.

The tremendous strides we have made in the last five years and the slack which must be absorbed in the training of the technician can only be appreciated by an examination of our pre-war status. Returning again to the War of 1812, there is a contract in the archives of the Ordnance Department's Watervliet Arsenal in which the standard inch is attached to and made a part of the contract. This standard inch is enclosed in a small envelope and consists of three grains of wheat which, when laid end to end, constitute one inch. The standard measuring tools were the rule and caliper. While the standard inch had managed to acquire some stability, the opening of World War I found the rule and caliper still the basic measuring tools of the machinist. World War I gave the micrometer and dial indicator to the average shop man. To a limited extent it introduced the use of gages in mass production. However, the gage programs of the military services were late in starting and never gained enough inertia to carry themselves. In most plants one could hear an old hand say, when the accuracy of his trusty one inch "mike" was challenged, "I've been usin' them mikes for ten years and they always been right before." Manufacturing could be conducted on this basis because machining was usually confined in one plant and there was no problem of interchangeability with items produced in another plant.

True, this period had produced some advancement in this field. During World War I the automotive industry learned the requirements of interchangeability in sub-contracted parts, and the inherent savings in making a product "right the first time." They developed automatic gaging devices of a refined nature. Western Electric and Bell, under the able leadership of H. F. Dodge, H. G. Romig and several others, had made great strides in the development of inspection on a quality control basis. Pipe must be interchangeable regardless of manufacture. As a result the petroleum industry has been driven to rigid standardization and gaging of threads.

But in the average shop a set of gage blocks was a showcase item for advertising purposes if it existed at all, and such large decentralized manufacturers as Westinghouse and General Electric had not established central control of measurement.

In the pre-war period little or no training was offered, either in precision measurement or in quality control. Some technical work had been done by the engineering societies — A.S.A., A.P.I., A.S.M.E., and A.S.M.C. The International Business Machine Company has instituted a course of study in precision measurement as a part of their company training program. Their text, "Precision Measurement in the Metal Working Industry," is comprehensive and widely-used for instruction purposes. One program should receive special note—that of the U. S. Army Ordnance Department. It was a program designed both to train personnel and to make engineers conscious that measurement control had a part in efficient production. This work was largely the work of Colonel H. B. Hambleton, then a civilian in the War Department. He had entered the Department during World War I in the Ordnance Gage Section. Remembering the difficulties encountered, he bent every effort toward the goal of providing every Ordnance District with a laboratory located in a college or university close to the industrial area. These laboratories served to train officer recruits and reserve officers in that district and act as a standby for emergency. A number of such laboratories were established—as was the laboratory here at Carnegie Tech—and were available to the school for class work, research or consulting in return for the space and assuming responsibility for the safekeeping of the equipment.

During the Defense period, educational and defense contracts of the services began to lay the groundwork for more effective dimensional control. Manufacturers, seeing scrap pile up in their plant, began to realize that they had never had adequate control, dimensionally. They quickly turned to gages for accuracy in their product. Inspectors for these programs were trained largely in the plant or in the E.S.M.D.T. programs.

The largest contribution, however, was a product of the war itself. A

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For DISCUSSION of this paper see pages 808-812.

product of the necessity for the conservation of manpower. Up to that point saving had been reflected in greater output per tool when rejections were reduced. Then, with the army and navy taking more and more men, it became necessary to see how the mechanics of production might be altered or improved so that each person could produce more units. For some time manufacturers and some government agencies had been inspecting on a percentage basis. The switch to a percentage basis usually occurred when it became physically impossible to manually inspect piece by piece the units produced, and automatic inspection equipment was either impractical or had not been developed. Or again, the switch was made when production seemed to be of satisfactory quality. The Ordnance Department, working with Western Electric, A.S.A., and several noted research engineers—one Dr. Working from C.I.T., adapted quality control to the problem of the Services by a method known as Standard Sampling.

It would seem that 100% inspection would produce a consistently perfect product. In actual practice, errors are introduced in 100% inspection through repetitive mistakes resulting from fatigue, necessity for speed, and attitude that if the part is not right "it's only one." Quality control recognizes that the product will not be completely perfect and minor defects may even be acceptable if not too numerous. By carefully gaging and actually measuring in borderline cases, the statistical possibility of defects or defective material may be accurately determined. The result is a product with an established quality level determined with a minimum of manual labor. Savings in manpower were tremendous: the end of the war found inspection cut *as much as 90% in many plants.*

Having established the pattern of the progress of measurement control and quality control, where to now? One of the Pittsburgh members of the Instrument Society, in going over my articles for the magazine he edits, has corrected on several occasions my use of the word "processing" to indicate manufacturing procedures involving metal removal. He explained that "processing" is usually identified with the chemical industries. For now, I acquiesce—and while I am with people identified with these industries I shall limit myself to the proper use of the word. However, if the word means continuous operation, then measurement control, properly applied, can put "processing" in the metal working shop. Automatic production depends on the ability to physically follow operation with operation and maintain the system in adequate control at all times. Measurement control can now provide the latter.

In this connection two things must be impressed upon industry: First, measurement control involves more than a standard sampling method of inspection and, second, the most lucrative application could not be touched by the Army: control *during* production. Here perhaps it would be well to differentiate between measurement control and quality control. Quality control in its present usage connotes inspection by standard sampling—a statistical analysis of the product of a manufacturing or processing procedure. It is broader than measurement control and could be applied to chemical processes, sales programs and management systems. The Gallup Poll depends upon a standard sampling system. It is one of the tools used in measurement control. Measurement control is used in the metal-working industry to insure continuous production of interchangeable items.

Measurement control is planned standards—standards which can be met; accurate standards—accurate because of regular recheck; good gages — speedy and positive — in process inspection — catching the trouble before it starts; it's gage surveillance, tool surveillance, gage block checks, standard samples, sublots, first sample, second sample. It's how we know a batch of gunpowder is good without blowing it all up. In short, it's all that goes into assuring a "good product—right the first time."

With such a substantiating case I might at this point argue that measurement control should be a specializing field under the Mechanical or Industrial Engineering Curriculum, such as Heating and Ventilating, or Power Plant. But quality control applications may be made in almost any field of mechanical or industrial engineering. Obviously it is not a broad enough subject to require a complete curriculum and probably never will be. Where then should it fit in the preparation of an engineer? The broad concept of quality control should be made a part of the basic engineering course — measurement control an elective matter in Mechanical or Industrial Engineering, depending upon the pattern in the particular college.

I believe every calculus course in any engineering school should contain problems designed to explain the principles of standard sampling and should identify these problems with subject. Each engineering college is faced with the problem of presenting to the engineer the basic principles of the other fields of engineering. In this program the opportunity will arise to present the principles of both Quality Control and Measurement Control. Perhaps this will occur in a Plant Management or Machine Shop course in one of the mechanical or industrial courses offered for the other fields. At any rate, the engineering graduate in any field should be familiar with the terms quality control, measurement control and standard sampling; and should realize the benefits which may be derived from planned quality.

For the student in Mechanical or Industrial Engineering who wishes additional specific training, two elective courses might be offered, perhaps to be taken together:

First, a recitation and survey course in Measurement Control of two or three hours per week. It should include the following: an elaboration on the formulae previously presented in calculus with specific problems in the development of standard sampling lot sizes; principles of interchangeability including any analysis of fits and dimensioning systems; principles of design of gages with particular emphasis on automatic inspection equipment; and finally advantages of in-process inspection. This latter should be the focal point of the course. It can be dramatized by a trip to a plant at which such control has been installed. At that time comparative figures should be presented showing saving occuring from the installation of the system.

Second, a laboratory course of two to four hours per week covering practical gage design; principles of precision measurement; and a practical problem of a before-and-after comparison type illustrating the value of dimensional control at the machine. The capital investment in the laboratory could be as modest as $10,000 and still be adequate for such a program.

Although to my knowledge there is no text available covering all of these subjects, the course could be built from material from several books. Some of the proven training media are: F. H. Rolt, "Gages and Fine Measurements" in two volumes—the patriarch; "Precision Measurement in the Metal Working Industry" in two volumes—a textbook developed over years of training at I.B.M., and now published by Syracuse University Press. A.S.A. Bulletins 1.1 and 1.2, and 1.3; Western Electric Company Monographs on Single and Double Sampling Methods; Walter A. Shewhart, "Statistical Method from the Viewpoint of Quality Control"; and Colonel Leslie E. Simon, "An Engineer's Manual for Statistical Methods."

Quality control and precision measurement should be popular courses in extension schools in the immediate future and should be broken down for management and shop personnel. They could be divided approximately as the electives suggested above, with the class and survey course offered for management personnel and the lab course for shop personnel.

As in so many other fields, the war has given tremendous impetus to a brand new technique. That it is new is evidenced by the fact that there is no adequate survey book covering the entire field. In your survey course, unless you are near a Western Electric plant or an automotive manufacturer, you will have difficulty in finding measurement control installed at the machine. Such basic problems as accurate measurement of a hole and standardization of surface finish on a practical basis still remain unsolved for the most part. The answer to continued advancement in measurement control lies in instilling in the neophyte engineer confidence in the attainability of "a good product, right the first time."

Note.—The first paper, "Instrumentation and Atomic Research," by Professor A. J. Allen, is not to be pubished

Concepts of Heat and Temperature

By A. G. WORTHING, Physics Department, University of Pittsburgh

WHEN one investigates elementary texts of physics in use at the present time with thoughts of heat and temperature in mind, he arrives at certain astonishing conclusions. (1) A large fraction of the texts do not in any way define what they mean by heat or temperature. (2) There is much inconsistency about the concepts developed where definitions of those terms have been given. (3) Despite lacks and inconsistencies, the discussions in the field of heat are basically much alike.

The importance of this subject with respect to courses in Instrumentation may be said to be commensurate with the importance of heat and temperature measurements among all measurements made daily by scientists, engineers and technicians.

Let us consider first some of the published concepts of heat.

Author No. 1 states, "Thermodynamics deals with . . . transformations . . . in which energy of work manifested by bodily movements takes the new form of a hodge-podge of invisible molecular movements called heat." From this we conclude that, to that author, heat is synonymous with the translational kinetic energy of molecular motion. Nowhere does he suggest any variation from this concept of heat. Moreover, certain other authors seem to agree with this limited concept.

Author No. 2 states, "Temperature is merely a question of the kinetic energy of the molecules, but heat combines with this the number of molecules which have this energy." This is not a clear statement of what heat is thought to be; but one may infer that, possibly in addition to the translatory kinetic energy referred to by Author No. 1, this author would include the rotational kinetic energies of its component molecules.

Author No. 3 extends the heat concept further. He says heat "is now held to be . . . the kinetic and potential energy of the molecules composing bodies." When, with the addition of heat, a body expands or changes in phase as from a solid to a liquid, a portion of the added heat certainly is used in separating or rearranging its molecules with a consequent increase of potential energy.

Author No. 4 states that "Heat is the energy of the molecules and atoms that compose a body." If we assume that the word energy includes potential and kinetic energies, his concept by the inclusion of atoms is to be considered as broader than those of the preceding three authors.

Author No. 5 states that adding heat to a body results in (1) increasing the kinetic energies of its molecules and its free electrons, (2) increasing the potential energy of its molecules, (3) increasing the kinetic energies of the atoms and electrons inside molecules. It is not quite clear what the author intends; but, if the changes in energy that are mentioned are to represent changes in the heat content of the body, we would say that according to this statement heat would be synonymous with internal energy — a term much used in thermodynamic discussion. Although it is quite certain that Author No. 5 would not identify the two terms as synonymous, there is no doubt but that many do.

Possibly the variations in the concept of heat which have been noted are the result of authors' loose statements. Possibly, knowing otherwise, they oversimplified matters intentionally. Whatever the case, the present author is certain, from discussions in a meeting of physics teachers and in graduate classes concerned with Basic Concepts in physics, that the various points of view presented above are held by both students and teachers.

Obviously the statement of author No. 5, in which heat seems to be identified with internal energy, is preferable to the other statements. However, it does not seem to be wholly satisfactory. Consider what happens when, as we say, 540 calories of heat are added to 1 gram of water at 100°C. or, what is effectively the same, when 972 Btu. of heat are added to 1 pound of water at 212°F. In each instance the water is completely vaporized without change of temperature. But what about the internal energy? If we check up we find that the internal energy increases have been only 500 cal., not 540 cal., and 900 Btu., not 972 Btu. The differences 40 cal. and 72 Btu. represent work performed in pushing back the atmosphere. The question arises: shall we say that the gram or the pound of water has had its heat content increased by 540 cal. or 500 cal. in the one case, or by 972 Btu. or 900 Btu. in the other case? Among teachers and students there is confusion here.

Perhaps the best and most workable concept of heat will differ rather radically from the foregoing. It is the concept which appears in connection with the First Law of Thermodynamics, the equation for which is usually written as

$$Q = \Delta U + W$$

of which Q represents the energy added to the body or system in consequence of a temperature difference, ΔU the increase in internal energy of the body or system, and W the work done *by* the body or system *on* other bodies or systems. Q is ordinarily called heat added. In accord with this basic equation heat is defined as energy being added to a body or system in consequence of a temperature difference. After the energy is once added, it is no longer viewed as heat but as internal energy or as energy transferred by virtue of work performed. Zemansky in the first edition of his Thermodynamics gives an interesting analogy. Heat and internal energy are likened to rain and water in a lake. When the water drops are falling they are referred to as rain. Once, however, the drops reach the surface of the lake, they cease to be rain and become lake water.

Referring back to the vaporizing of water at the boiling point, but with the First Law of Thermodynamics in mind, we now say that 540 cal. of heat are added to the water at 100°C., that the internal energy of the water is increased by 500 cal. and that 40 cal. of work are done by the water in pushing back the atmosphere.

This usage of heat as energy in the process of transfer because of a temperature difference covers most cases, though not all, where, whatever our definition, we have considered the term heat appropriately used. In accord with this view, we correctly speak of the conduction of heat by a gas, and the radiation of heat from a hot body to a cooler body. However, to speak of energy stored in a body, that is its internal energy, as heat would be quite inconsistent with the First Law of Thermodynamics and would lead to difficulty in thermodynamic calculations if such energy were so considered.

Incidentally, the foregoing justifies the term radiant heat to which many, including the present author, have objected. So strong has been his prejudice against this usage in past years that even now that term seems unsatisfactory. The term radiant energy is accepted instead. However, there is no escape from the fact that, thermodynamically, what is referred to is heat, and may properly be called radiant heat.

Summarizing with regard to the term heat we may say that various concepts are commonly held and that of these only the concept of heat as energy in process of transfer because of a difference of temperature, in accord with the first law of thermodynamics, seems most free from objection.

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For DISCUSSION of this paper see pages 812-818.

Let us consider next, in a limited way, the concept of temperature.

In physics texts temperature is ordinarily treated as a "quantity" which, like mass, length and time, is fundamental for problems and discussions involving heat. On the other hand, there are those who declare that temperature is just a convenient term for the average translational kinetic energy of a molecule of the body under consideration, or, as some prefer to state it, the energy per mole associated with the translatory motion of its molecules. Whether or not temperature or, for that matter, some other "quantity" in the field of heat involving temperature, may be viewed in this or some similar manner and expressed in terms of the basic mechanical "quantities" mentioned, is the question under consideration here.

If the temperature of a body is merely a measure of the average translational kinetic energy of the molecules of the body, we should be able to write

$$T = k \times \tfrac{1}{2} m (v^2)_{Av.}$$

If we should select *on this basis* a temperature unit that would fit in consistently with other units of the c.g.s system, k would automatically become unity. Accordingly, we would say that, when the average translational kinetic energy of the molecules of a body is one erg per molecule, the body has a temperature of one erg. The temperature of some hydrogen, say, at the melting point of ice thus expressed in ergs would then be 5.66×10^{-14} erg. Obviously the erg would be an inconveniently large unit of temperature, and one can understand why it would be desirable to take 2.07×10^{-16} erg as one centigrade degree.

If physics were strictly classical, the foregoing identification of temperature with translational energy per molecule might reasonably stand. In the field of the classically ideal gas, the policy of identification does not give rise to difficulty. But gases, even ideal gases in the region of absolute zero where they become degenerate, are not classical; and liquids and solids are much more nonclassical. Where quantum numbers are small, the distribution of energy among the molecules of a body is very different from the classical expectation.

Even at ordinary temperatures, when dealing with substances whose molal specific heats have not reached the Dulong and Petit limit of $3R$, one must conclude that the classical equipartition laws fail so far as the equilibrium between a solid and its vapor is concerned. The velocity distribution of the vaporized atoms of carbon, say, is not that of the surface layers of the solid carbon from which the evaporation has taken place. Though the solid and its vapor may be in temperature equilibrium, the average translational kinetic energy of the vapor atoms need not, and generally will not, be the same as the average translational kinetic energy of the atoms of the solid. (That some prefer to ascribe the internal energy of solids to stationary waves does not alter the situation.) Even in the cases of mixtures of such simple gases as helium and argon, when the temperature is so low that the energy is confined mainly to small quantum numbers, the average kinetic energies of the helium atoms will differ from the average for the argon atoms. On the concept that the temperature is a measure of the average kinetic energy of the molecules, the argon and the helium, though in equilibrium, would have different temperatures. Quantum considerations very strongly oppose the concept of a translational energy-temperature proportionality.

Elsewhere* it is shown that other suggested identifications of temperature with other physical characteristics is as unsatisfactory as that one discussed above.

Our precise definition of a temperature scale is based on an application of the Carnot cycle proposed by Lord Kelvin. Where Q_0 and Q_1 represent, for a particular cycle, the quantities of heat absorbed and liberated, respectively, by the working substance used in the Carnot engine, this scale requires the corresponding temperatures T_0 and T_1 to be so related that

$$T_0/T_1 = Q_0/Q_1.$$

This scale is based on the assumption that energy is conserved in macroscopic processes, on the supposition that all possible p,v,T changes may be produced reversibly, and on the second law of thermodynamics. Developed in the days of classical mechanics, these basic assumptions and the temperature scale are equally applicable to the phenomena of the present-day quantum mechanics.

That we should go back to the first and second laws of thermodynamics for clear, usable concepts of heat and temperature is both interesting and significant. It is not astonishing, however, since most of the underlying theory concerned with their measurements is based on those laws.

*American Journal of Physics, Vol. 8, Feb. 1940, pages 28-30.

Surplus Instruments for Education

By W. G. POLLARD, Professor of Physics, University of Tennessee, Knoxville, Tennessee

THE fact that this Conference is being held to explore the matter of instruction in Instrumentation in the engineering schools emphasizes the importance that is being attached to this phase of engineering education. There is, of course, evidence from many directions of the increasingly important rôle which instrumentation will play in future industrial development in this country. The universities are already being called upon to engage in specialized training in this field designed to develop an understanding of the fundamental principles underlying various types of instruments and to produce an acquaintance with the variety of applications which have been made of them.

If the universities and engineering schools are to be able to accomplish this objective successfully, a great deal of expensive equipment of specialized nature is required. Few of them are in a position to make even a small fraction of the expenditures involved. The budgets of the majority of these schools are barely sufficient for the purchase of the usual items of equipment required in the major fields of engineering education. Instruments are, in general, expensive items, and few schools can afford the purchase of more than one or two of them a year. The prospects for effective instruction in Instrumentation in the near future are, therefore, poor, unless some means are found for providing the schools with the necessary equipment at a small fraction of its initial cost.

A possible way of meeting this situation is provided by the regulations for the disposal of surplus property. It may well be that a sufficient supply of instruments suitable for training purposes are already to be found in Army and Navy stores or among the disposable properties of their contractors. When such property is declared to be surplus, it would seem proper that it be made available to schools without charge for the purpose of implementing this training program. Two basic arguments may be advanced in support of this point of view. First, the financial resources of the majority of universities have been greatly weakened by the war so that their inability to adequately support the type of training we are discussing is in part a direct consequence of the war. From this point of view, the disposition to them of property acquired for its prosecution and no longer needed is quite proper. The second argument is based on the severe shortage of tech-

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nically trained men and women which this country now faces as a result of the near cessation of technical and scientific training during the war years. Is it not proper that surplus war property be used wherever possible to help relieve this situation? Moreover, many of the students in the next few years for whose training such equipment would be used will be veterans. Surely it is only right that property created for the prosecution of the war should now be used to help complete the training of the men who fought it.

The overall picture for surplus property disposal is not yet entirely clear. However, in the case of Army property, a procedure has been set up which embodies these principles in a very commendable way. This procedure consists briefly in the following steps: Lists of equipment giving a description of each item desired are prepared on standard forms and submitted for approval to a local university committee and to the State Office of Education. Such approved lists are then sent to the Army Service Forces Command for the Corps Area in which the institution is located and from there are transmitted to the nearest RFC Surplus Property disposal. unit. Any item on this list which the unit has in stock or later acquires is then made available free of charge to the school submitting the list.

This system has several important disadvantages from the standpoint of the schools which are worth listing here:

1. The Universities must prepare want lists without knowing what is available.

2. The official RFC list of available equipment may not describe the instrument in the same terms as those used by the Universities.

3. There is a great possibility that instruments attached to equipment which is not useful to schools will be described with the equipment. Obviously instruments should not be robbed from equipment which has further utility, but care should also be taken not to lose instruments because of poor description of available property.

4. When instruments are sent they are very likely to have essential parts missing. Also they may be removed from a plant by unskilled persons, resulting in great damage to the instrument (*e.g.*, clipping of calibrated tubing leads to expansion bulbs). Thus the system is likely to be wasteful in damage to valuable property.

In spite of these difficulties, the Army procedure is excellent in many respects and it may be as near an approach to the desirable objectives which have been advocated here as the pressure of immediate circumstances and the magnitude of the whole problem of surplus property disposal will allow.

It would seem to be a proper function of this Conference to investigate steps which may be taken to assist the schools in using this procedure to obtain suitable equipment for instruction in instrumentation. Specific information about types of instruments which may appear in surplus stocks is needed. In this respect instrument manufacturers with some knowledge of the quantity, types and models of instruments now in use by the Army and by Army contractors could be of great assistance. The schools will need guidance in preparing their want lists in such a way as to avoid acquiring outmoded or useless equipment while at the same time passing up good equipment through lack of knowledge of it. Requests for surplus property should be coördinated with other sources of instruments for the schools in such a way as to achieve the greatest degree of balance in the final instrument laboratory at the least cost to the school. Effective means are required to assure that essential parts of instruments obtained in this way are not missing or badly damaged. This would probably involve supervision of the removal of instruments by a representative of the university or of the manufacturer.

Thus, to conclude with a specific recommendation, it seems clear that one of the most important ways in which this conference can advance the cause of Instrumentation in the University would be to develop a detailed set of instructions to guide the schools in the best means for implementing the army procedure for the acquisition of surplus instruments. It could also investigate and make recommendations on possible modifications of the existing procedure.

Instrumentation Appreciation

By R. D. WEBB, Chief Instrument Engineer, Carbide and Carbon Chemicals Corp., Charleston, W. Va.

LIKE many others in industry I have often grumbled about the quality of the graduates of our engineering schools. Here I have been given an opportunity to do something, or at least to say something, about it and I will have to confess that I am at a loss as to what to recommend.

The main complaints I have had about the average young engineer were three: (1) The weakness of his knowledge of the basic physical laws; (2) his inability to attack a problem and persevere to a conclusion, and (3) his poor written reporting of his work. These criticisms are so broad that they cause me to wonder if I simply don't expect too much of the young engineer and of his training. Anyhow, none come *directly* within the scope of the conference and so I'll discontinue talking of general complaints and presume to make a specific suggestion.

How the present four-year curricula can be made to absorb additional technical courses is beyond my ability to answer, especially in view of the fact that engineering schools are already open to criticism because their curricula are so starved of cultural subjects. Nevertheless, I'll make my recommendation. The course I would propose is one for undergraduates, one which might be called "Instrumentation Appreciation" or just "Industrial Instruments."

It would start off with a study of industrial measurement devices. Pressure devices such as the Bourdon tube, metallic bellows, diaphragms, mercury manometers, and possibly including the electrical types, would be examined and adequate coverage given to the details of actual installation. By the last, I refer to methods of accurately conveying the pressure to the measuring device. The water-filled lead to the steam pressure gage is a common example, one generally recognized by everyone, if the gage is below the line. But, place that gage twenty or thirty feet above the line, and you have a minor problem in engineering, for the lead may be full of water, or of steam, or of a gas such as air or carbon dioxide. This problem becomes serious at low pressures, particularly in the subatmospheric range, and is amplified when the fluid being measured has its condensing temperature in the atmospheric range.

Temperature measurement would cover the various expansion, pressure and electrical means, listing and comparing their characteristics. As with pressure-measuring instruments, here again stress need be placed on proper installation, only in this case we usually take care to take the detecting device to the fluid being measured, whereas with pressure we took the fluid to the device.

My recommendation would be to devote a goodly share of the time allotted to the course to a study of flow metering because of its broad usage in industry. It is a vital part of the steam generation and combustion field; it enters into many phases of the automotive field; it is almost the operating heart of the chemical and oil industries; and it even enters into axe factories and armor plate plants.

The remainder of the measurement section of the course could be a brief coverage of several of the many other instruments used in industry, such as the pH and conductivity recorder, the various automatic gas and liquid ana-

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gers, including spectrometric, and possibly a limited outline of simpler electronic and photoelectric devices.

Automatic control has played a very important part in our recent technological advances and so demands consideration in this course. Colonel Bradley Dewey, our recent Rubber Director, named it as one of the four great technological developments in the building of our new but tremendous synthetic rubber industry. Let me quote from his 1944 Chemical Medalist acceptance speech: "The synthetic rubber industry could not have been built without a tremendous utilization of our great technological developments of the last two decades. These were: First, high-temperature catalytic cracking for the production of monomeric materials; second, pre-fabricated welding of piping or steel, field-welded in place; third, high-alloy steels for superheating hydrocarbons as well as steam; and, lastly, *the control of temperatures, pressures, and the flow of fluids within close limits by automatic control valves actuated by remote control instruments.*"

A survey of the available regulators and controllers could be made and possibly the theory of control could be touched. Give the student the few simple formulas which will permit him to size control valves, and perhaps give him a description of, and reasons for, using the various types of these valves. Incidentally, control vales offer one of the most interesting phases of instrumentation, and are worthy of study. Today's valve, if properly applied, will do wonderful work, but, generally speaking, still needs improvement in regard to packing, friction, erosion of plug and seat, shut-off properties, rate of response, and sturdiness and vibration resistance under critical and flashing flows.

If the undergraduate learns something of modern instrumentation, he will be in a better position to be of help after graduation. If he steps into a plant not thoroughly modern, he will be in a position to recognize this fact. If he goes into one that is, he will not be at a loss, but will be familiar with many of the things being done and with the equipment doing it. A course in Instrumentation Appreciation should make him more valuable in industry.

Plans for Coöperation in Instrument Education

By H. E. FERGUSON, Plant Testing Engineer, Peoples Gas Light and Coke Co., Chicago

THE Instrument Society of America has not, as yet, formulated definite plans for a program of educational activity, or for coöperation with educational institutions. So I am not an official messenger of the I.S.A., and my remarks are not a formal declaration of its policies. But I have conferred with many of the officers and leaders of the organization, and I hope to present the gist of their ideas concerning instruction in Instrumentation and in measurement and control devices.

A basic idea prevalent among members of the I.S.A. is that any educational programs concerning instruments should not be limited to the thirty (or forty or fifty) thousand students enrolled in technical colleges and universities, but should provide equal—or even greater—opportunities for men in industry to increase their knowledge. Many graduates of technical schools, who are now actively engaged in engineering or technical work, do not possess adequate knowledge of instruments and control devices; quite a few lowly chart-changers earnestly desire to know more about what they are working with; more than one instrument salesman or service-man should learn more about equipment other than that which he is trying to sell. It is desirable that baccalaureate curricula contain courses in instrumentation. But, whether they do or not, serious consideration must be given to making instruction and training in that subject available to two or three million industrial employees.

To insure as wide a coverage of this potential student body as is possible, many members of the I.S.A. feel that the activities of the Society in promoting education should be directed toward the attainment of three distinct goals:

1. The establishment of courses in instrument theory, design, application and testing, as parts of curricula of technical schools and universities, with credits toward baccalaureate degrees for their successful completion;

2. The development of a number of "short courses" (or seminars) on the use and maintenance of particular types of instruments, these courses to consist of four or five days of intensive practical instruction without scholastic requirements or credits;

3. The formulation of correspondence courses which would cover the instrumentation requirements and practices of specific industries.

COLLEGIATE COURSES

Some of the courses in Instrumentation that were established in technical schools to aid war material production and to fulfill needs of our armed forces have been the subject of much favorable comment. It is felt that many technical colleges and universities might well adopt at least parts of them. Any candidate for a technical degree should receive a minimum of two full semester-hours of instruction and training in Instrumentation—and more preferably two full year courses: one semester or one year on indicating and recording instruments, and one on controlling, transmitting and integrating devices. Too many technical graduates don't know that a temperature recorder merely records variations in temperature and is not a temperature measuring device.

The Society would like to concentrate its initial efforts in this field to coöperating in the establishment of such courses in three eastern, three central, and three western technical schools or universities. Because the courses would be a part of the general technical education of the students, they would be sponsored, directed, and operated entirely by the faculties of the various schools—with the I.S.A. offering to act in an advisory capacity.

SHORT COURSES

The "short courses" that are contemplated would be similar in character to the "Southwestern Short Course in Gas Measurement" sponsored by the University of Oklahoma with the aid of meter companies, and the companion course at the University of West Virginia. They would be definitely planned to interest and benefit technicians, foremen, and supervisors in various industries: men who have at least a couple of years of working experience, or who may even be in fairly good positions but wish and need to learn more about their equipment in order to advance. The courses might be held during a spring or Easter vacation (as at Oklahoma), or in the early part of the summer just after Commencement. They would be limited to four or five days so that, with the traveling time, they would not require the student to be away from work more than a week.

Each short course would be limited to a particular field, or a specific type of instrumentation—and would include intensive education in theory and thorough explanation of practical applications. In addition to the flow-metering courses already established, the society would like to see comparable short-courses in such subjects as: (a) pyrometry and thermometry; (b) vibration and sound equipment; (c) mill or shop gages, calipers and inspection devices; (d) industrial electronic devices; (e) electrical indicating instruments; (f) strain and torque devices.

In view of the enormous number and wide variety in use (or in misuse!) in industry today, short courses in pressure gages and allied instruments would be profitable to many technical men. The above are only a few of the possible subjects for interesting and valuable short courses.

At least two courses in each subject should be made available, one in the East and one in the West. The number

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of short courses at any school might well be limited to two: one in the spring and one in the summer. The courses would be chosen and sponsored by the engineering schools of the universities or colleges; the direction would be jointly by the engineering faculty and the I.S.A.; and the teachers and instructors would be persons actively engaged in the use of the equipment, and technicians from instrument manufacturing companies. The last day of the course might well include a clinical conference on practical difficulties encountered in the field as reported by the students.

The expenses of such courses might be defrayed in most part by registration fees (as is done at Oklahoma), although these fees are usually paid by the students' employers. The services of the instructors and teachers would be gratuitous, or would be borne by instrument companies. The thought has been expressed that campus schools in small towns would be preferable—as a safeguard against the courses degenerating into "conventions."

CORRESPONDENCE COURSES

Correspondence and extension courses are desired which will cover instrumentation in particular industries or parts of industries. For example, it should be possible to formulate useful courses to cover instruments and control devices used in:

steel mills,
refrigeration plants,
electric power plants,
maritime transport,
building construction,
gas plants,
mines and ore treatment mills,
petroleum refineries,
heating and ventilating,
dairy products.

In formulating and operating a correspondence or extension course covering the instruments and control equipment used in a particular industry (such as one of the above), the school or university could expect and would undoubtedly receive the support and coöperation, not only of the I.S.A. and various instrument manufacturers, but also of engineers in that industry and of technical societies related to it (such as the American Petroleum Institute, the American Gas Association, the American Institute of Electrical Engineers, etc.).

I'm willing to bet that every person in this room, at some time or other, has written to an instrument company and requested a copy of some bulletin or pamphlet concerning a certain gage or indicator or regulator—just to find out how the thing was constructed and operated. So it should be recognized that for many years the instrument companies have been unconsciously conducting a rather haphazard and inefficient sort of correspondence course in limited branches of instrumentation. More formal and more comprehensive correspondence courses than the foregoing are desirable to make available to workers, who cannot leave their jobs to enroll in a school or college, means of constructively and definitely correcting their lack of knowledge or understanding of equipment they must use. Of course, *after* the curricula of all technical schools and colleges contain Instrumentation courses, and after enough short courses have been established to correct the deficiencies of those who cannot attain collegiate levels, there might not be much need for correspondence courses in instrumentation. But that day seems far away.

SUMMARIZATION

Many people in the instrument field believe that definite avenues of education in the design, use and maintenance of technical instruments are needed—and that these avenues of education should not be restricted to the campus but should go deep into the heart of industry. Certain members of the I.S.A. desire, and are anxious to coöperate in, the establishment of at least three separate avenues:

(1) formal collegiate courses in Instrumentation;

(2) short courses in particular types of instruments;

(3) correspondence courses in instruments of industries.

These avenues of instrumentation education need not conflict or interfere with one another: often they can supplement or complement each other. Furthermore there can be little doubt that all of the various parties involved will be benefited. The student and the worker will obtain a better understanding and greater knowledge of equipment that they must use in earning a living. Industry will benefit through better application and maintenance by employees of the instruments it must purchase. The instrument manufacturer will benefit through better understanding and greater appreciation of the operating benefits and economies that can be attained by use of his products. The technical schools would benefit through increased potential student-bodies, and more direct contacts with sources of first-hand technical information.

PROCEEDINGS OF WEDNESDAY MORNING SESSION, OCTOBER 8, 1945

A Visual Aid for Instruction on Electrical Instruments

By D. A. YOUNG, Manager, Instrument Engineering, Westinghouse Meter Division, Newark, N. J.

WHEN I was asked to talk I thought perhaps I should say something about what educational institutions should do in the way of training people to fit into our type of industry, but I felt that I was unqualified to speak on that. Instead, I want to tell you about a means that we have prepared at the Westinghouse Instrument Section in an endeavor to teach something about instruments in a quick, brief and concise way.

This method I am going to show you has not been widely used; yet we hope it will be used more extensively. It is a method we have prepared for teaching the fundamentals of electrical instruments such as we manufacture.

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For DISCUSSION of this paper see pages 818-824.

This started out during the war period, when instruments were used in such huge quantities, and so many new people came into contact with them, that it became necessary to find some way to let them know what goes on inside an instrument.

The Government sponsored various schools, night schools, free schools, to anyone who could come and be told about instruments. They solicited the aid of men from industry, engineers and salesmen who knew the subject, and used these men as teachers. This started out as a course which was just thrown together. Because of its effectiveness, however, the International Brotherhood of Electrical Workers asked that something similar be presented to their people. Such a course had to be done in a matter of one day, and it was repeated several times, and out of it grew something that sounded pretty reasonable. Then the Brotherhood asked that we prepare this in some form that could be used *by their own people* in teaching other members of the Brotherhood.

We started out to prepare a booklet, just a repetition of what had been said, together with pictures which had been shown in the form of slides.

Then we got ambitious and decided that this was not enough: we would also make records to go along with it, and the result was a sound-slide film. You all know what they are.

By the way, I have quite an advantage today, in that you are not going to have to listen to me all the way through; you are going to listen to a master at speaking: Mr. Dell Chambett of N.B.C. (You may have heard him on the Ford Sunday Evening Hour and the Radio Reader's Digest programs.)

We were able to prepare and rehash many times, what is said, and he went over it several times before we made a recording of it.

This sound-slide film takes a total of 50 minutes to run off. It tells about the fundamentals of construction and application of electrical instruments. It is available to anyone who wants to use it. However, it is divided into several sections, covering the four basic mechanisms which are used in electrical instruments, and I am going to take out just one of those sections.

This one is on the permanent-magnet moving-coil type, which is used for measurement of direct currents and voltages and also, by means of auxiliary equipment which you will see, can be extended to other applications.

[. . . Showing sound-slide film . . .]

As I indicated in the beginning, my objective here was not to try to tell you about instruments, otherwise I would have had to show the entire series of these films. My objective was to show you a means which we have worked out for teaching.

We gave a lot of time to deciding how to present this. We thought of writing it in a book, and in fact, there is a book which summarizes everything that is said or shown in this sound-slide film. We thought of trying to have speakers go around and tell this story wherever it was wanted, but we decided that it would take too many people. But primarily the sound-slide film is the thing.

[EDITOR'S NOTE—We were requested to obtain and print the list of all six sound-slide films which are the subject of Mr. Young's address. They are as follows: (1) General application of electrical instruments. (2) Permanent-magnet moving-coil types for use on direct current and for use with rectifiers and thermocouples. (3) Electrodynamometer mechanisms for current, voltage, power frequencies and power factor. (4) Moving-iron mechanism for alternating current and voltage. (5) Rotating-iron types for synchroscopes. (6) Ten different considerations in the selection of instruments, such as Recording, Panel type, Switchboard, Portable, Vibration, Temperature, Influence of magnetic panels or external fields, etc.]

Educational Preparation for an Instrumentation Career in the Electronic Industry

By H. B. RICHMOND, Chairman of the Board, General Radio Co., Cambridge, Mass.

IN the earlier years of our life events which in later life would pass unnoticed often leave a lasting impression on our memories. One such event has stamped itself indelibly on my memory. It was associated with my first position after graduation from college. It was in the heyday of expanding public utilities and my employer was Stone & Webster. The gentleman who engaged engineering graduates delighted in trying to find out from them why they wanted the particular position they were asking for. The great Mississippi River dam at Keokuk was just being completed and electrical interest was focused on hydroelectric power. Whenever an applicant appeared who stated that he desired to go into the hydroelectric business this inquiring gentleman always asked "why?" and "what position" he desired. The "why" was easy, but the position always became vague, so he readily prompted by inquiring if the applicant desired to push logs away from the penstock intake, to patrol transmission lines, or stand switchboard watch in a generating station. He soon had the average applicant completely floored. He had obviously studiously avoided all reference to rate structure studies, systems operation analysis, sales, and public relations just to impress on the average applicant how really little he knew of the hydroelectric industry and, more particularly, how little he had really thought about what being employed in it really meant.

I am to talk about Educational Preparation for an Instrumentation Career in the Electronic Industry. This is an area large enough to have its boundaries defined by airplane distances, yet just what does it really mean? Is Instrumentation a thing apart from other applications? And how widely are we to interpret the word *electronic*, which yesterday had special charming properties all its own but today must share them with its twin brother "atomic"? But let us be practical and shorten the rhetoric, and simply say that we will confine our discussion to methods of *making measurements* and to the *recording of data* by means of circuits of which the vacuum tube is an important component. This takes us out of the field where an extremely sensitive indicating instrument such as the unipivot type or light-beam galvanometer *directly* provides the desired data.

Our definition becomes somewhat clouded unless we stretch it to include *electronic measurement means*, even if the device under study is in itself out of the strictly electronic field. For example, I read a technical report the other day on studies of controlled rockets such as those mentioned by General Marshall in his recent public release on the status of the Army. This report contained these two significant statements: "Instrument design is still our first goal before going on to motor development"; and also "Telemetering equipment is being developed to be used for flight tests of sample missiles. It will convey to the ground station information on the operation of the missile (such as temperatures, pressures, accelerations, control hinge moments, etc.). Preliminary estimates indicate it will be possible to transmit each of 30 readings thirty times a second." Within my definition this is instrumentation in the electronic field. Nine hundred measuring-instrument readings per second! Transmitted to a ground station from a supersonic-speed missile!

Some of the more common instruments in the electronic field include noise and vibration meters, signal generators, vacuum-tube voltmeters, oscillators and detectors extending from audio-frequencies to a centimeter of wave-length, all kinds of monitoring equipment for broadcast stations regardless of frequency system or frequency of the transmitted wave, and that myriad of measurements whose answers appear on a cathode-ray screen. The embryonic field of radar navigation must not be passed over hurriedly. On measurements hinge vast new possibilities in the field of communication, the potentialities of which are expanding at a rate faster than most minds can fully comprehend.

Yes, this field of electronic measurements has expanded in a "regenerative" manner—and also not too unlike the action of the atomic bomb. What yesterday appeared to be prosaic and routine has today become a field too vast to be covered by the usual four-year undergraduate course. What then are we to do about it?

First, what do we want to do about it? If we are trying to expose the student to the possibilities of instrumentation in the electronic industry, that is one thing. But, if we want him to become an instrument designer in this field that is quite another matter. Let us discuss them separately.

It would be helpful if every engineering student could have some training in electronic instrumentation. It is essential that electrical and mechanical engineers receive such a training. Advanced students in physics have been purposely omitted because it goes without saying that electronic techniques must be part of their program and also because this paper deals primarily with the training of engineering students. I feel that most good engineering colleges, particularly in electrical engineering, do have reasonably satisfactory courses in electronic measurements. These same institutions a quarter-century or more ago gave good courses in ordinary direct-current and commercial-frequency measurements. Starting with the philosophy and mathematics of the precision of data, labora-

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tory work included simple measurements by the Poggendorf method, Wheatstone bridge, calibrating measurements by the potentiometer method, the Varley loop test, Carey-Foster, Anderson, and the usual bridge techniques. As the communication field advanced, the special testing techniques particular to it were introduced and some of the older procedures dropped. Ultra-high frequencies are simply pushing the frontier forward and imposing greater responsibilities on the staff giving instruction in electrical measurements. The word radar has become such a national by-word that instruction in pulse techniques is mandatory, at least in electrical engineering. For an alert staff this advancing art should present no unusual problem other than that all-engulfing one—that of how to include this material in a limited time schedule. I am becoming increasingly concerned with the difficulty of covering the necessary ground in a four-year course. I believe it can be done if the aim is a general educational background based on engineering but I am becoming very pessimistic of giving a satisfactory specialized training in that period.

Now let us direct our attention to the more specific problem of actually training men to specialize in the field of electronic instrumentation. I doubt if many students would deliberately select such a course. This is fortunate. I believe that, in general, training should be given in a much wider field than that in which the student intends to specialize. This is necessary both to give him a better viewpoint in his field of actual specialization and to enable him to have a wider field of employment from which to choose. Thus I find I am forcing myself into the position of declaring that *the best training for a career in electronic instrumentation is a sound training in general electronic engineering.* Let us examine what such training should consist of.

I have sat on electrical engineering department visiting committees and well realize the thoroughness with which curricula are discussed. There is the usual recognition of the need for basic grounding in Mathematics and Physics, the proper use of English, as well as the specific subjects required in the professional field. My observations are more particularly those of an employer of engineers in the electronic field where the larger part of the work is in instrument design—or, more properly, in *apparatus* design. The professional subjects have become so numerous that *adequate* coverage *cannot* be given in a four-year course. I have become increasingly aware of the truth of Professor Harry Clifford's statement: "A four-year course does not make you an engineer, but only an engineering possibility."

The policy of the company with which I am associated is in general to employ only those who have taken their master's degree. Our principal exceptions are in the direction of those who have a doctorate. In general the latter group is engaged in advanced circuit design rather than in actual apparatus development. We have found little to support the thought that engineering in electronic instrumentation is less of an intellectual challenge than research in physics or a career in law or medicine, all of which presuppose the attainment of graduate degrees. Our basic preference is for those who not only have a master's degree but also who have had industrial coöperative work, thus bringing to the student actual applied experience while he is still in the intellectual absorptive period.

There appears to be a growing trend toward the elimination of the so-called practical courses because of the time demands of the technical courses as technical frontiers are pushed forward. In the field of Instrumentation this is to be regretted. Sketching, mechanical drawing and actual working knowledge of machine tools and manufacturing methods are of tremendous importance to the successful instrument designer. The mere fact that a signal generator utilizing the latest pulse techniques can actually be made to operate with the desired precision is often a real achievement. It is, however, of little value to a manufacturer of electronic measuring equipment unless it can be manufactured at a price which will make it attractive to prospective customers. Too many circuit engineers require the assistance of a mechanical engineer to reduce their developments to practice. This is a practical working method, but it results in the usual conflicts of ideas between the two engineers with the resultant increased cost of development. This increased cost is just another way of saying that the engineers are of less value to their employer. A single well-equipped engineer would be of more value to himself and to his employer.

In summarizing I should like to place emphasis on the two following points: First, the need of general background instruction in the meaning of instrumentation with adequate emphasis on electronic methods to all engineering students; and, second, for those students who plan to make a career of electronic instrumentation that the course of instruction be general even in the specific field and that it lead to an advanced degree. While specific suggestions have been made as to some of the content of the course, no specific content can take the place of the right sort of instructor. Men who can make the subjects sparkle with life and, preferably, who themselves have breathed the life of industry and commerce, can do far more to inspire the student than can those who present a course poorly, no matter how meticulously the course has been laid out. I firmly believe that engineering instruction should be so designed that it develops first the man, then the mental tools necessary in his profession and, finally, that it leave him with an insatiable desire to keep abreast of or contribute to, the technological developments in his chosen field. While I am not particularly optimistic of the contributions to be expected in this field from university research, I do favor the members of the staff participating in such a research program in order that they may personally be examining the ever-widening horizons in this field. Carefully planned, fully supervised, university-industry coöperative courses are favored because they have two great advantages. The student is familiarized with the realistic aspects of the subject he is studying, and a closer relationship is brought about between professor and industry engineer to their mutual advantage.

Educational Activities of an Instrument Manufacturer

By L. F. PARACHINI, Educational Dep't, Weston Electrical Instrument Corp., Newark, N. J.

TANGIBLE assistance, service, to those engaged in educational pursuits has been a policy of the Weston Electrical Instrument Corporation since the very beginning. Assistance and service has, of necessity, taken many forms and has been rendered in ever-increasing scope as the demands of educational institutions and students have increased.

This paper is a summary report on our educational activities as they pertain to the student and the teacher in the technical colleges, technical secondary schools, and vocational institutions. It discusses the various publications, films and lecture activities with the view of informing and if possible provoking comment, so that the best purposes of industrial-educational coöperation may be served.

Undoubtedly, as evidenced by the calling of this Conference, there is to be increasing emphasis on education as it involves the science of Instrumentation. It is important, therefore, that our future educational activities be commensurate with the requirements.

The dissemination of information on electrical indicating instruments, the theory of operation, construction and scope of application has been accomplished through three principal media. First, through the publication of numer-

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For DISCUSSION of this paper see pages 818-824.

ous monographs, wall charts and circulars dealing with the many-sided story of the electrical indicating instrument and its accessories. Second, through the use of educational films. Third, through the medium of lecture service provided by thoroughly trained, competent engineers.

By these principal means, and others as required, we have kept the student and his teacher informed as to basic principles involved, as to uses and importance of instruments and as to new developments in the art. The fundamental relationship between scientific progress and measurements has been continually evaluated in the educational service rendered.

It was from the beginning that the needs of the science student, be he teacher or pupil, were recognized. It was in 1910, early in the company's existence, when the first of a long line of educational monographs was produced and made available.

Monograph B1, the first, was written for the high-school and college-preparatory level. It covered the subject of the permanent-magnet moving-coil instrument as reduced to practice in the Model 1 and Model 280. Discussing a then little-known subject, the monograph constituted a basic text. It detailed the development of the permanent-magnet instrument, discussed the fundamental theory in simple terms and outlined some experiments to be performed by the students.

Records do not indicate how many were distributed, but it is recorded that it was one of the first examples of the industry serving the educational institution through the medium of a free authoritative publication. "Monograph B1" was widely sought and extensively used.

"B1" proved to be the foundation on which a series of monographs was built. They discussed a variety of subjects, such as "Principles of Permanent Magnet Movable Coil and Movable Iron Types of Instruments" (B-7) and "The Photronic Photoelectric Cell" (B-8).

Each monograph of the series was written by a member of our organization. Inevitably, therefore, it bore the engineers' viewpoint with its industrial complexion rather than the educator's. This was desirable since the technical schools had as yet developed little instructional material on instruments and Instrumentation.

More recently the trend has been to present the teachers' viewpoint. "Monograph B3" of the new series is a case in point. The author is Mr. Robert Stollberg, Fellow, Bureau of Educational Research in Science, Teachers College, Columbia University. "B3" was produced under a fellowship supported by Weston, not only financially but also out of its background of experience in preparation of educational literature.

The title, "Suggestions for Teaching Selected Material from the Field of Electricity," indicates the extent to which the educator's needs have been considered. The approach and terminology are intentionally not those of the engineer or electrical theorist but are developed along the lines of general education. The monograph begins with a discussion of energy resources and extent of their use; it follows with a survery of knowledge, misconceptions and interests regarding electricity prevalent among young people; and it discusses methods teachers may employ to determine these facts about their students. Teaching objectives are presented, and methods of approach and useful activities for teachers are outlined. Finally the theory, construction and use of electrical measuring devices is treated on the basis of general education and in such fashion as to be of value to teachers who may or may not be highly technically trained.

On a different tack, such publications as "Electrical Testing in Industry" and "Electrical Measurements and Meter Testing in the Power Plant" have been made available. For these specialized subjects the services of a consultant, Mr. E. S. Lincoln, were used in order that the industries' viewpoint could be properly evaluated. These publications, although pointed to the industrial user, have been valuable to the student in advanced engineering courses.

Monographs have been an effective aid to the educator. That this is so is established by the numerous requests for even the presently out-of-date "B-7." That this is so is established by the fact that many texts have incorporated illustrations and textual matter from the various monographs we published. We have assisted in preparing much of the instruction material on electrical indicating instruments.

Published material has not been limited to monographs. Wall charts for example have been made available for display in the classroom or the laboratory, showing in enlarged detail the various instrument mechanisms. This type of instruction matter proved very effective in the recent armed forces training programs. As a matter of fact the Weston Company supplied many air base training centers with a group of six charts illustrating the various aircraft instruments of its manufacture. These and the three charts illustrating the PMMC, the moving-iron and the electrodynamometer instruments are available on request.

The "Instrument Sketch Book" is widely known. This special-purpose publication has been used as a summary of the general instrument lecture and distributed to the audience that it might have a record of the material discussed. The Sketch Book is novel in its presentation and is, to our best knowledge, the only source of illustrations and basic discussion of the six instrument mechanisms used in indicating electrical instruments. Its original cover of scientific "doodles" has probably caused some sleepless hours, posing, as it does a few thought-twisters for the inquisitive mind.

The first printing of 10,000 has been depleted, attesting to its popularity and effectiveness.

It should be obvious that the more complex subjects of instrumentation pertaining to electrical indicating instruments, as well as the fundamental facts, have received attention from the educational viewpoint. Engineering data on special devices such as the copper oxide rectifier, Photronic cell and electronic photoelectric potentiometer, have been supplied to schools for their use in instruction. In these publications the treatment is on a pure engineering basis and thus suitable for the more advanced students.

Judged by present standards the Weston Educational film was poor. Judged by 1927 standards, the year of its production, it represented an advance in the field of visual education. Using all the tricks of self-assembly of instruments and animation, the film eloquently told the story of the construction of the three generally-used electrical instrument mechanisms, the permanent-magnet moving-coil, the moving-iron and the electrodynamometer.

The film did yeoman service in reaching a wide audience and, since there were relatively few industrial films of its type available, did serve to broaden the general knowledge of instruments.

Today the picture is changed. Visual aid in education has come into its own. This fact rather than simplifying our problem has caused us to decide against the use of films for the present. There are at present at least a thousand films of all sorts intended to be used in the school. There are many more in production and contemplated. Any attempt, therefore, to use any new educational film will have to be evaluated in terms of its place competitively with many others of similar nature. After all, only a limited time is available for their showing.

Because the production of good films with sound, animation and color costs roughly $10,000 to $20,000 a reel, it is very important that careful consideration be given to its over-all effectiveness as compared with other media of transmitting information.

Our present view is established because of three failings of a "canned" presentation — failings which in our opinion justify non-conformance with the present trend. First, "canned" lectures cannot establish the proper level of presentation which may vary with each group. It must of necessity operate on a sufficiently low intellectual plane to include all of its audience. This tends to oversimplify the story. Second, it cannot answer questions or discuss tangential matters which may develop within any group of interested people. Third, it lacks personality, a characteristic which imprints any activity involving people in the minds of its participants.

In the final analysis any commercial

undertaking must in the over-all sense pay its way. Perhaps not necessarily in dollar return but in the long-range view of good will established. We believe that under the circumstances outlined our best interests are not served through the medium of educational films.

Instead we have expanded upon a tried formula. Used for the past fifteen years, our Lecture Service has been the means of continually informing college students and engineers in the broad subject of Instrumentation. This activity, since it constitutes a vital link with the educational institutions, has been maintained at a high level. The lecturer is a man of engineering training, very completely informed in the factory manufacturing procedure as well as the theory and practice of the electrical indicating instruments he discusses. He is in a position to do that which the film cannot: to shift text to meet the conditions existing, to answer any and all questions and to provoke discussion of the subject. Lastly he must impart a personality in order to make a lasting impression and thus drive the subject home.

Past procedure has been to offer lectures to technical engineering colleges as frequently as deemed desirable from the educational institutions' viewpoint. As a rule a cycle of three years (once in three) has proven desirable to most schools except some highly active ones from an Instrumentation instruction standpoint.

The future plan is to continue this arrangement. Expansion of the activity will be necessary to include additional schools and to cover some of the more specialized vocational arts institutions.

As a rule the lecture is built up around the discussion of the six basic mechanisms: polarized iron vane, hot-wire, electrostatic, moving-iron, electrodynamometer and permanent-magnet moving-coil. Much can be said about these basic units which is not directly covered in general engineering texts. The story is further expanded to incorporate the numerous accessories such as shunts, resistors and the like which are necessary to make the basic mechanisms do the job of making the innumerable electrical measurements required in practice.

The visual aspect of teaching is not overlooked. A very necessary part of the lecture has always been the examination of actual instruments, usually at the point of the lecture in which they are under discussion.

A display of especially prepared transparent-case instruments and actual parts is the tool of the lecturer. This tool is used instead of slides or motion pictures.

This is the actual device. See it! Examine it! Heft it! Operate the switches! Turn the binding post tops! How much more effective this is than to look at a picture. This is the psychology behind the lecturer's display kit. The laboratory and the factory are brought to the classrooms in a physical sense by the act of displaying the finished product and its parts—many represented in various stages of completion.

There can be no doubt of the effectiveness of the actual over the picture illustrations when one considers the world fair exhibits, the auto shows, power shows and the like. The crowds gather about the gadget, not its portrait.

As the most effective medium of fulfilling the basic tenet of our educational policy, we have found no substitute for the lecture. Accordingly it is intended that this activity will be carried out in the future on an increasing scale until such time as developments in educational procedure dictate a change.

As additional aid and service it is intended that we will continue to produce monographs and educational literature as the need develops, both for the student and the teacher.

In addition it is intended that close coöperation with educational institutions will be maintained as a means of continually studying the trends in methods and thinking, that we may be cognizant of their needs and better fulfill them.

It is further intended that we will maintain an open mind and change our activities as conditions warrant.

This paper has outlined briefly our educational activities with a twofold purpose: (1) to indicate to educators what has been done for their assistance and what is available for the future; (2) to develop criticism and concurrently suggestions for changes as may be necessary.

Specifically it would be of benefit to have an expression of opinion of educators on such questions as:

1. Are you familiar with our various publications of an educational nature?
2. Have the publications to date been of sufficient scope to meet the needs in fields intended?
3. What are the requirements of commercial literature for the scientific student?
4. Have you made use of the lecture service?
5. Are you prepared to make greater use of this facility?
6. What is your opinion of films, silent, sound, black and white or colored and of film strips for the presentation of such subject matter as is involved in the discussion of electrical indicating instruments?
7. Does the industrial organization have to participate in education or can the job be done entirely by the educational institutions?

The Army Industrial College — an Instrument for Perpetuating Industry-Armed Forces Teamwork

By Colonel WALTER H. E. JAEGER, Director, Department of Research, Army Industrial College.

THE officer who should be here this morning is General Armstrong, who is the Commandant of the College. Unfortunately he could not be here and asked me to represent him, and to express his regret for not being here with you, since one of the most significant parts of the program of the Army Industrial College is the organization of industrial advisory committees, likewise committees from the scientific institutions, the educational institutions of the United States, which participated in this war effort and brought it to a successful conclusion.

It is a very difficult and indeed a trying task to persuade the people of the United States at this time that planning for a future national emergency is an absolute essential if we are to survive. We observe a constant pressure on the legislative bodies to return the soldiers to their civilian occupations, and I am convinced that the pressure from within is as great or greater than the pressure from without.

Nevertheless, after the last war, when a similar tendency was very discernible, the Congress enacted the National Defense Act of the ninth of June 1920. That statute was based on certain experiences gleaned during World War I. If you recall, during that particular emergency there were many false starts; there was much confusion in Washington. Indeed, there were those who suggested that Washington had a virtual monoply on confusion. Some have carried that thought with them to the present day. Into this welter of confusion, however, there was introduce a definite and specific instrumentality for a planning of industrial mobilization for a future emergency. That was a part of the National Defense Act, namely, Section 5-A.

That part of the Defense Act created an Assistant Secretary of War, now known as the Under-secretary, and charged him with the responsibility for

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For DISCUSSION of this paper see pages 818-824.

supervising all planning for industrial preparedness for a future national emergency. And more specifically, it charged that officer of the War Department the Assistant Secretary, with a complete planning activity.

Under the Assistant Secretary there was established on the 25th of February, 1924, the Army Industrial College, as one of the agencies to assist in carrying out this function of planning for a future emergency from the point of view of industry. At the time, the College had a single department known as the Department of Instruction, and the function of that department was to train Army officers in the ways of industry, and especially procurement.

A year after the establishment of the College, that is to say, 1925, Naval officers were added to the student body and to the faculty.

Somewhat later, Army and Navy officers were assigned from time to time to various industrial establishments, so that they might learn at first hand the ways of industry and not just from pictures and diagrams or lectures.

Today, however, the plan of the College has changed somewhat, and in addition to the Army and Navy officers, it is understood that key civilians are to become a part of the student body in the first postwar course, which will begin on the fourth of January of the coming year, 1946.

In the interim period from January, 1944 to the present, over 4,000 Army and Navy officers and civilians have been trained in the work of contract termination, at the express direction of the Under-secretary of War. But this mission is soon to conclude, and then in January, the work of training officers in industrial mobilization planning for a future emergency will begin in earnest.

Prior to 1942, when the activities of the College were suspended for two years since all of the members of the staff and faculty and student body were needed in actual procurement functions, the College had been distinguished by a rather complete monastic celibacy and seclusion. As General Armstrong has said, the officers seemed to have taken at least two of the three vows that the monastic orders generally take. I leave it to your own judgment which vows.

Now, however, the College has emerged from its chrysalis and is actively engaged in maintaining the relationships of the Armed Forces with industry. At this very time, a board of general officers and flag officers, together with key civilians, is meeting in Washington in order to determine the future purposes of the College and also to change the name. We would like to offer a prize, gentlemen, for a suitable name. Many have been proposed, but not one has been found that is entirely suitable to express the new mission of the College: That is, the union of the Armed Forces and industry in this postwar activity. That is, from one point of view it is postwar, and we hope that it won't be prewar. That is taking the long range view.

The theory of the Commandant is that the proverbial ounce of prevention has now become worth a ton of cure, in light particularly of the most recent developments, such as the atomic bomb. However, General Armstrong discounts somewhat the completely revolutionary effect of the atomic bomb, and for the following reasons: He suggests that in the past gunpowder undoubtedly was regarded by those who had to suffer its effects somewhat as the Japanese—and for that matter the rest of the world—may look upon the atomic bomb. On the other hand—and I am aware of the fact that General Groves said no later than last night that no countermeasures had been devised (that means as of now) — we assume that undoubtedly there will be those who will be working in the laboratories on possible countermeasures against the atomic bomb.

In the meantime, however, it is our duty and grave responsibility to plan in the light of what is currently known and what is currently to be expected.

As to the organization of the college, a striking innovation has come into being, aside from the joint effort of the Armed Forces and industry, in that there has been in existence, since the seventh of March 1944, a Department of Research which has as its primary function the development of the basic facts of the period of industrial mobilization that we have just gone through.

Here we find a group of earnest and enthusiastic research analysts who are probing the various governmental agencies, and especially the emergency agencies who are making haste to depart. These gentlemen are searching for the mistakes, the deficiencies that may be discernible in the operations of these agencies. When we recently prepared a series of charts to find out what happened to the various functions that were proposed in the Industrial Mobilization Plan of 1937 in the event of an emergency, three huge wall charts were not sufficient to record the names of all the agencies that had the duty at one time or another of administering these functions. We hope by 1960 to have a master chart ready to show what happened to these functions.

We do not approach the agencies with a blunt request for a statement of their sins of omission and commission. We simply ask this question: If you had to do it over again, how would you do it? It serves the same purpose, ladies and gentlemen, and is much more painless.

The Department of Research is organized into certain operating groups. The manpower group—which is considered by the Commandant as one of the three legs of the tripod on which rests the industrial preparedness of this country—examines not only the population of this country and its division by sex, by industrial skills, by regions, by age groups, by physical capabilities, but it studies and analyzes the population groups of other countries. There isn't really very much point, ladies and gentlemen, in studying merely our own industrial potential, our own war potential—it must be studied in relation to that of other countries.

So we have in addition to this manpower studies group a material studies group, which examines the raw materials and the natural resources of our own country, again in relationship with similar resources of other countries. Then we have a group which may be of special interest to you, the industrial facilities group. Here the analysts examine the productive capacity of the various plants, the factories or, as our British cousins put it, the "works," and relate this to the location of these plants from the point of view of security.

And one of the principal research projects is that which deals with dispersion. Yet in many respects the ideal dispersion and a blueprint for it must remain theoretical rather than practical, because we have no way of persuading the manufacturers and the producers to remove their plants from present locations, which may be ideally situated from a competitive point of view, and have them install these factories and plants in huge caves in the Rocky Mountains or the Alleghenies. You can readily understand that the manufacturers might balk, likewise that the taxpayer might not be ready to part with his money in the furtherance of such an apparently chimerical scheme.

But what we can do is to plan it and hope that the transition won't take so long that by the time the transition is finished, or before it is begun, there will not be a United States.

The theory is that an instantaneous total mobilization plan is essential. There are countries in the world that can move much more rapidly than ours. There are countries that by slight pressure on a push button can produce the war machine full-panoplied from the brow of the directing genius. In this country, conventions, conferences and other slightly organized methods of wasting time [Laughter] seem absolutely essential to accomplishing the objective. This is what causes the planning authorities in Washington to spend sleepless nights.

That and the extraordinary lethargy, the firm determination to return to normalcy, that is, the normalcy of the sports page, the financial column, and above everything else, the comic strip, that seems to animate the vast majority of the people.

So we have progressed through three of these research groups, and in addition, we have what is known as the seminar studies group, and there, apparently, we are guilty of the sin that I have just described, that of having conferences. In fact, we have had well over a hundred conferences with lead-

ers of industry, of the government, and of the armed forces. These conferences are recorded and the most secret and valuable information is carefully filed away in safes.

This is the working material of the student at the Army Industrial College. That is where the people from the Petroleum Administration—and heaven knows, they have been roundly cursed, as have all the people in Washington; the people from the War Production Board — and they seem to live on a vocabulary of profanity; and all the other people who have tried to do something in Washington, come and sing their swan song, how it could have been done better, why it wasn't done better, how it should have been done.

Now it is hoped that we can start our planning where the actual constructive results left off in this war. And yet inertia will still continue to exist. We are not possessed — and it may be that I should add, thank God we are not possessed—of an organization that discards all human liberty. But as a substitute, then, for this highly efficient organization where one pushes a button and everybody marches without question, perhaps as a substitute we require a very intensive education as to the need for industrial preparedness, so the next time there won't be an industrial Pearl Harbor. The Armed Forces' Pearl Harbor was bad enough, but an industrial Pearl Harbor might prove fatal.

So there in these seminar studies that I have referred to, we explore the actual industrial mobilization in this war, and we are greatly assisted by the numerous industrial advisory committees that have been formed, in the iron and steel industry, the machine tool builders, farm equipment, the antifriction bearing, the cotton textile people; there are a dozen or more of these committees in existence, and General Armstrong is most eager to see a similar committee organized among the members of the Instrument Society and hopes that such a committee will come into existence.

He has asked me to extend a very special invitation to the members of the Society and also to the representatives of the Carnegie Institute of Technology, to form a committee where one of the most vital of all of the contributions of industry to the winning of the war may be perpetuated. These advisory committees, as the name implies, aid the Armed Forces in the actual planning that is carried on. They tell the War Department and the Navy Department whether a given plan is practicable and feasible or not.

The Armed Forces cannot plan in a state of vacuum—that has been attempted and it doesn't work. Industry, after all, knows how it is to be done and it is the experience of industry that the Armed Forces must utilize constantly if a workable industrial mobilization plan is to come into existence.

Perhaps the greatest emphasis of all is on the time lag, that is, the time from the attack until the country is actually able to retaliate. This time interval has been steadily reduced by the extraordinary advances in science and technology, and so therefore the time interval that is shown in the plan must be correspondingly reduced, but perhaps in even greater proportion.

I have endeavored this morning to tell you something of the Army Industrial College, its history and organization, and above everything else, the mission that it has by statute and by regulation. In behalf of General Armstrong, the Commandant of the Army Industrial College, I want to thank you very much for your kindness in inviting a representative of the College to appear this morning. I do appreciate your kind attention.

Professional Status and Training of Instrument Engineers and the Rubber Industry

By ARTHUR W. CARPENTER, Manager Testing Laboratories, B. F. Goodrich Co., Akron, Ohio

DISCUSSION of the professional status and training of men for instrument engineering by one who is not a specialist in that field seems inappropriate until one considers that the work of the instrument engineer spreads over and vitally affects nearly every scientific, technical and production activity which exists in modern industry. Those whose duties lie in these other fields constantly use the products of his specialized technical skill and look to him for the assistance which he can render in the handling of their problems through his ability to design, construct, apply and maintain in proper working order the innumerable devices which provide the precise measurements and the indispensable control on which all industrial success depends. Perhaps, therefore, one who has spent many years in industry constantly utilizing the products of the efforts of instrument men, enjoying contacts and association with them and in fact, assisting at times in the selection and preliminary training of young graduate engineers desiring to enter the instrumentation field, may bring to this Conference on Instrumentation and the University a point of view and perspective which have value in supplementing the ideas of those more directly concerned with the specific details of instrumentation work.

The rubber industry is one which has become highly instrumented during the past thirty years, the period of its most rapid growth. The enormous growth of the industry was mainly a response to expanding automotive and aviation requirements but it has been dependent also, to a degree often not appreciated, upon the development of improved methods of measurement permitting accurate and rapid evaluation of new products and techniques as well as upon the application of automatic control to production processes resulting in greater efficiency and better quality and uniformity of product. Without these contributions — which were direct consequences of improved instrumentation—it is doubtful whether either the quality or quantity of rubber products produced could have been adequate to meet the needs. Nearly every important unit of the rubber industry now has a separate instrument department charged with the responsibility of *designing, specifying, applying and maintaining* the instrumentation employed throughout the organization. These departments are headed by thoroughly experienced instrument men, staffed with competent engineers and mechanics skilled in this field and provided with suitable workshops for their purposes. Their services are utilized in practically all of the production and technical divisions of the organization. The rubber industry may therefore be considered an excellent and typical example where the training and professional status of instrument engineers may be investigated.

Before turning to consideration of instrument engineers in the field of rubber (or in fact to the present-day status of instrument men in general) it may be well to give brief thought to some of those who were forerunners in the field, those who developed and applied some of the earliest instruments. What were their essential qualifications and what was their status in the world of their time? What changes have since occurred and how have these altered the situation?

Instruments for weighing were among the first and the ordinary balance was in use in the early Egyptian era but its origin is hidden by the dim mist of prehistoric time. In the field of optics, Seneca, the Roman philosopher of the Pythagorean and Stoic schools who lived during the time of Christ, commented on the magnification effect of a glass

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For DISCUSSION of this paper see pages 818-824.

BERGMAN

CARPENTER

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MARSHALL

SOME OF THE SPEAKERS FROM MANUFACTURING AND PUBLIC-UTILITY COMPANIES

globe filled with water though he knew nothing of the light refraction which caused it. Claudius Ptolemaeus, the celebrated Egyptian astronomer and mathematician who was born in 70 A.D., was familiar with the laws of light refraction and even dealt with curved surfaces in his writings but, so far as is known, he never discovered the magnifying power of curved bodies caused by their refractive action. Lenses were invented sometime between Ptolemaeus and Roger Bacon, the great English monk and philosopher educated at Oxford and Paris who wrote his general treatise on the sciences in 1266-1267 A.D. Bacon discussed lenses in detail but made no claim for their invention. In his old age, he even wrote that he was unable "to read or write without the glasses they call spectacles, lately found out for the benefit of old men when their eyesight gets weak." For three centuries thereafter nearly all of the work in optics was done by the spectacle makers who constructed both the first telescope and microscope. In 1590, a Dutch spectacle maker by the name of Jansen invented a compound microscope consisting of a convex objective and a concave ocular. Soon afterward, the German astronomer and mathematician, Johann Kepler, Professor at Gratz and later at Linz, demonstrated the advantages in the use of two or more convex lenses to obtain larger images. Kepler however depended on the greater mechanical ability of a less brilliant scientist, Christopher Scheiner, for the actual construction of the Keplerian telescope and microscope. In the field of heat, the thermometer for measuring temperature was invented by Galileo, the great Italian physicist and astronomer who was educated at the University of Pisa where he became a professor of mathematics, later removing to Padua and to Florence. He constructed a hydrostatic balance in 1586, a telescope in 1609 and his thermometer sometime prior to 1600. The thermometer was greatly developed by his pupils during the succeeding forty years and in 1641 the Florentine philosophers were using an instrument consisting of a bulb filled with alcohol with a sealed stem graduated according to an arbitrary scale.

Work with electricity is much more recent and it was not until near the end of the eighteenth century that Count Alessandro Volta, the Italian physicist who was a professor at Como and at Pavia, invented the electrophore, the electroscope, the condenser and the voltaic pile. After the turn of the nineteenth century, Ohm, the German physicist who taught mathematics at Cologne and at Berlin University and later became professor of physics at Munich, formulated the laws of current conduction. About the same time Ampère in Paris, Professor of Mathematics at the Polytechnic School and at the Collège de France, demonstrated the relation between electricity and magnetism. Then followed the discovery of electromagnetic induction in 1831 and the establishment of the laws governing electrolytic action in solutions, by Michael Faraday, the English physicist and chemist who was made professor of chemistry for life in the Royal Institution and who prepared the way for nearly all of the subsequent practical and industrial applications of electricity. Many followed in quick succession: Lord Kelvin, Professor of Natural Philosophy at Glasgow who invented the mirror-galvanometer and numerous other electrical instruments, a new compass and a tidal gage and who dominated the science of physics during his lifetime through his researches and inventions and was unsurpassed as a designer of delicate apparatus; Wilhelm von Roentgen, Professor at the University of Wurzberg, the discoverer of X-rays, Sir William Crookes, inventor of the radiometer as well as the Crookes tube; Heinrich Hertz, Professor at Bonn who devised a detector for the electromagnetic waves produced by oscillating circuits which had been predicted some 24 years earlier by James Clerk Maxwell.

These great pioneers in instrumentation and the countless others who contributed to its progress seem to have had certain characteristics in common. First, they were thoroughly trained in the fundamentals of mathematics and the physical sciences so far as these were known in their time. Then, too, they usually lived and worked in the thoughtful and studious environment of the university. The association of the university and instrumentation is particularly notable throughout this entire development. Furthermore, these men possessed inquiring minds. They were inventive, alert to new ideas and everlastingly conducting individual research to open new horizons. Finally, they had to have a high degree of mechanical skill and manual dexterity either in themselves or in the person of some associate so gifted through whom their ideas could be converted to actualities. In passing, it may be noted that most of these men occupied important positions among their associates—that they enjoyed great respect and high professional standing. These characteristics are as necessary today in instrument engineers as they were in earlier times but the difficulty of acquiring the proper training and of securing professional recognition has been enormously complicated by the tremendous expansion of scientific knowledge in widely diverse fields and by the advent of our industrial age with its mass production and regimentation.

In a modern mass production industry like rubber manufacture, the work of an instrument engineer covers so broad a scope that a young man fresh from school finds himself called upon to use detailed knowledge which is ordinarily classified in several of the different branches of science and engineering including mathematics, physics, mechanical engineering, chemical engineering and electrical engineering. He usually feels insufficiently prepared in some of these requirements because they are never all adequately covered in any single four-year college training program at present available in our universities and technical schools. He must have, also, marked ability to work with his hands and a strong curiosity as to what is happening and what makes it go. This extremely broad base for his activities is due primarily to the fact that such a comprehensive business recognizes no border-lines between the traditional classifications of technical knowledge but uses any process or tool which it can employ to good advantage, Over the years, the rubber industry has learned how to make and apply more than 30,000 different articles of rubber which are employed in all sorts of services for mankind and flow through the channels of commerce into nearly all other industries and human activities. In the manufacture and use of these products, it seldom is possible to segregate one process as entirely chemical and another as wholly electrical or mechanical. The border-lines overlap and anyone who is concerned with the measurement and control of what is happening must be

Continued on page 846

Radar Techniques in Instrumentation

By EVERARD M. WILLIAMS, Associate Professor of Electrical Engineering, Carnegie Institute of Technol

FOR the past few years we have been hearing a great deal about radar and associated military electronic equipment. Requirements for radar apparatus have resulted in a great deal of invention, development and refinement throughout the electronic art. It is certain that some improvements in the electronic art will influence instrumentation. It is the purpose of this paper to review briefly, with instrumentation education in mind, the direction that strictly electronic developments have taken and illustrate some specific instrumentation applications. These developments may necessitate some extension — if not modification — of course content where specialized advanced courses are offered.

Developments (other than the complete radar systems) in the electronic art associated with military radio may be summarized as—

(1) Tubes and circuits allowing improved functioning at very-high, ultra-high and super-high frequencies; and operation at frequencies for which no equipment formerly existed. By improved functioning we refer to the greater efficiency of oscillators and amplifiers, higher sensitivity of detectors, and greater power-handli[illegible] capacity of all high-frequency devi[illegible]s.

(2) A new and diversified f[illegible]mily

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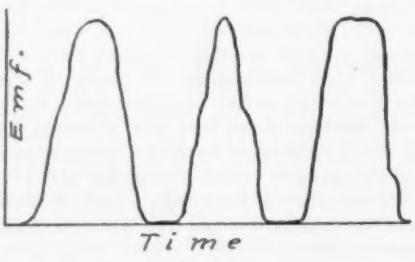

Fig. 1

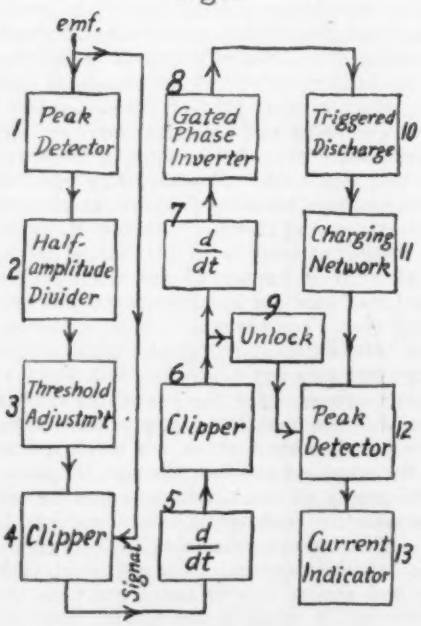

Fig. 2.

System Element	Function	Sketch of element output
1	Produces continuous emf. output proportional to peak of impulse.	
2	Divides emf. delivered by peak detector in half.	
3	Supplies threshold adjustment to clipper at ½ peak amplitude so that clipper output is portion of pulse up to a ½ amplitude horizontal line.	
4	Performs gating operations on signal as indicated in 3, above.	
5	Differentiating network. Delivers impulse derivative with respect to time.	
6	Clipper which flattens tops at predetermined level.	
7	Differentiating network.	
8	Removes positive emf. pulses and inverts polarity of negative pulses.	
9	Uses the positive pulse component of output of 5 above, to unlock the peak detector 12 so that it will function only during the duration of the original pulse rather than on the pulse intervals as well.	
10	When excited by a pulse this element short-circuits its output terminals.	
11	A constant-current element charges a capacitor which appears across the output of 10.	
12	This peak detector which is unlocked at time t_1 delivers a continuous current output proportional to the peak emf. (occuring at time t_2). It does not respond to the higher peak indicated as immediately following the t_2 peak since it receives no unlocking pulse for this. Its current persists until the next unlocking pulse.	
13	Current indicator giving observer direct reading.	

Fig. 3.

of vid* circuits—gates, flip-flop circuits, pulse-forming, -shaping and -utiliz g circuits, etc.

*The term "video" has come to apply to all circuits other than voice or telegraph communication and control, although originally intended only for the low-pass amplifier stages of picture (television or facsimile) equipment.

(3) A variety of display systems utilizing cathode-ray tubes.

New devices have been accompanied by improvements in components permitting reliable operation under unfavorable conditions of temperature, pressure, vibration, etc. It may now be considered a matter of standard procedure to design electronic systems to operate in the —54° to 71°C. ambient temperature range, continuously under 100% humidity, to withstand salt spray and even, if necessary, to withstand the enormous accelerations encountered in artillery projectiles.

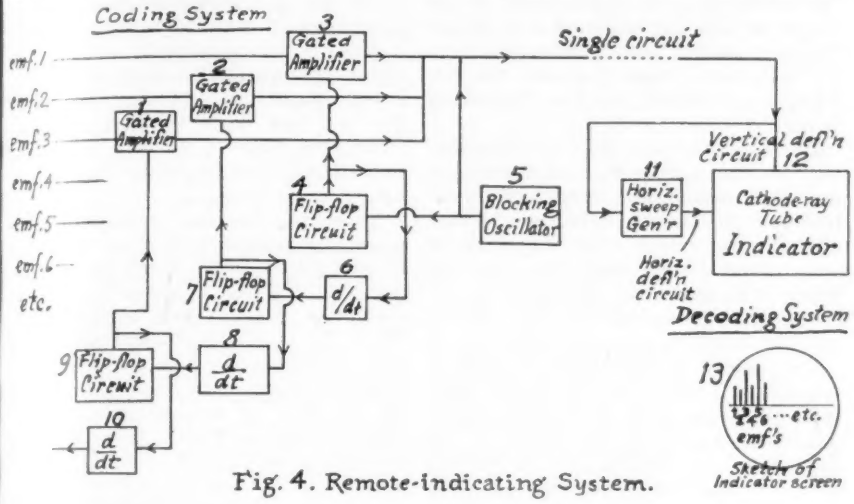

Fig. 4. Remote-indicating System.

System Element	Function	Sketch of element output
1, 2, 3	These are amplifiers which are turned off and on through impulses fed to their gating circuit. When an emf. appears at the gate circuit the amplifier 1, for instance, will amplify emf. 1. As soon as the gate emf. ceases, the amplifier ceases to function.	
4, 7, 9 6, 8	These flip-flop circuits when excited with a pulse from the differentiating circuits 6 and 8 will generate the gate-opening pulses. The flip-flop 4 is started by an impulse from blocking oscillator 5. The derivative of the trailing edge of its gate opening pulse triggers, through circuit 6, flip-flop 7, etc.	
5	This blocking oscillator supplies a large negative impulse which initiates the train of sequential gate-opening pulses in the flip-flop circuits. Its synchronizing impulse also appears on the circuit so that the indicator trace is initated at the correct instant.	
11	Synchronizing impulse from oscillator 5 starts horizontal sweep generator, which produces saw-tooth wave necessary for even spacing of gated amplifier outputs along the indicator trace as in 13 of Fig. 4.	

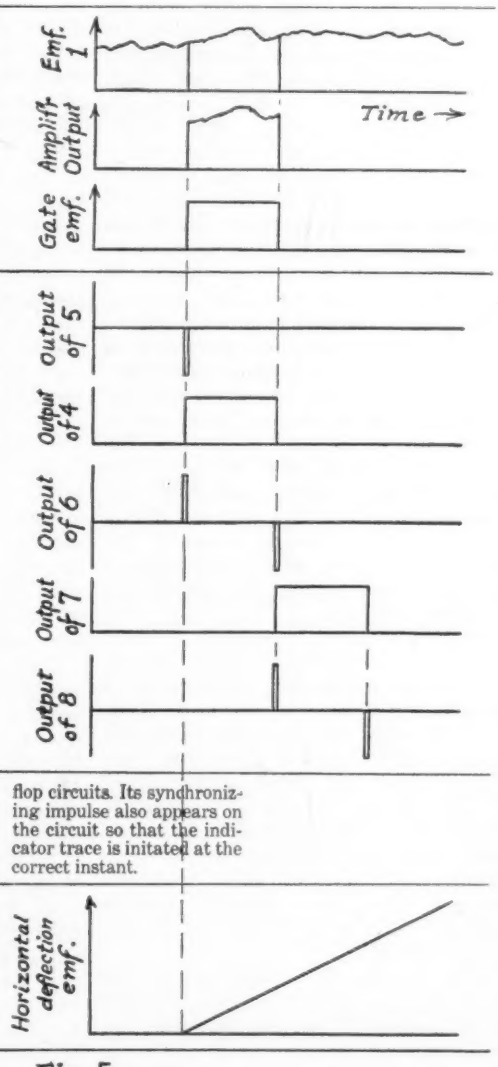

Fig. 5.

Electronic devices can be used in instrumentation systems: those in which electrical magnitudes are measured directly or those in which other physical magnitudes (force, temperature, acceleration, etc.) are converted into electrical magnitudes; changes in the electrical magnitudes (electromotive force, current, circuit parameters, etc.) are amplified, modified, or converted by the electronic system to derive the required indications. It is in the field of "derived" indications that the author anticipates the greatest use of radar techniques. Consequently most of the contribution to instrumentation will be from (2) and (3) above.

By way of illustration let us first consider the problem of deriving an indication from a physical magnitude which, when converted into electromotive force, varies in time according to the sketch of Fig. 1. The desired derivation is assumed to be a direct indication of the average duration of the pulse, with the duration expressed as the time interval between half-amplitude points on the pulse. A single-line block diagram of the radar technician's solution to this problem is shown in Fig. 2. In Fig. 3 the operation of the system is explained step by step. Such a system could be designed to function with pulses of approximately 1/3 microsecond or longer.

As a second illustration let us consider the system of Fig. 4. This was devised to give a simultaneous or nearly simultaneous remote reading of twenty physical magnitudes under conditions permitting only a single circuit between the system under observation and the indicator. This system is capable of giving readings in sequence with approximately one microsecond required for the transmission of each impulse and, therefore, with twenty magnitudes to be measured, can display each of these approximately 50,000 times per second. Step-by-step operation of this system is described in Fig. 5.

These illustrations are given to avoid answering specifically the query "Just what is a Radar Technique?" They convey an impression of immense versatility in electronic circuits; indeed during the war many radar technicians were characterized by a "state of mind" in which they believed that electron tubes and their associated circuits could be made to perform any and all functions that can be reduced to electrical magnitudes. Although the electronic method is not necessarily always the most profitable, some of this attitude will surely be of great value in the instrumentation art.

Instrumentation in the Electrical Engineering Curriculum

By FRED H. PUMPHREY, Educational Service Division, General Electric Company

I AM in a very enviable situation, in that nearly everything I had intended to say has been said, and therefore all I have to do is call attention to some of those points and draw some tentative conclusions from them.

Yesterday we had a number of very interesting talks. In one of them Mr. Webb called attention to the usual deficiencies of engineers—a weakness of physical concepts, an inability in handling electrical engineering techniques as applied to problems, and an inability to write good reports. After having some experience with the War Department in trying to write reports that could not be misinterpreted, my sympathy lies with the students. There was an indication, therefore, that further emphasis should be placed on physical concepts, on the techniques of problem solution and on the reporting of the results of these solutions.

Mr. Webb, Mr. Carpenter and Mr. Ferguson tied instrumentation and automatic control together, and in that I am very happy because it seems to me impossible for the colleges to set up a program on instrumentation as differentiated from automatic control: Those two are so closely allied that from the institutional point of view I think the colleges will want to treat them together. Mr. Ferguson also emphasized the need for *post-college training*, either in the form of short courses or correspondence courses.

Improved techniques such as sound-slide-films, wall charts, etc., were also mentioned by Mr. Young and Mr. Parachini, and I believe that it is possible to develop such a technique at the college level. Very little has been done as yet but I see no reason why it cannot be done. It means a sales program on the part of some of us in industry to persuade the industrial people to do some of these things, but I am not discouraged about that.

With this general background, therefore, I want to call attention to some of the statements of educational philosophy of the General Electric Company which have been made in recent years. The first is a paper written in 1941 by Mr. R. C. Muir, Vice President of the Company and General Manager of the Apparatus Department. Mr. Muir called attention to the soundness of the engineering program as of that time. He was right: the colleges on the whole have done a bang-up job, and the fact that their graduates don't know all there is to know about physics or science, or all there is to know about the techniques of engineering procedures, is not too much of a criticism because—as has been mentioned—there are only four years available for collegiate instruction at the Bachelor's level.

At that time Mr. Muir called attention to the possibilities of improving teaching techniques. Many of these teaching techniques have been developed in connection with the work of the Armed Forces, and when we are thinking in terms of setting up new instrumentation instruction we should not disregard those possibilities.

The second article which I want to mention is a recent one by Messrs. Boring, Stevenson and McEachron, published in April of this year in the *Journal of the Society for the Promotion of Engineering Education*. The authors oppose specialization; they plead for a more solid foundation of engineering science. They indicate an *interneship in industry* as the solution to specialization. They emphasize the need for a continuation of training into the post-college years—the plan which has been mentioned in this Conference. They stress leadership, that rather etherial quality which permits a man to get others to do the things he wants them to do and like it. They then call attention to one other item which has not been taken up in this Conference as yet, and that is the importance of the teacher.

How are you going to get instrumentation instruction in the colleges until the college teachers know instruments? Mention was made of short courses. Let me urge that the first short course be one for professors. In general the professors have to know so many subjects that it is almost impossible for them to keep up-to-date on everything, and, gentlemen, the members of the Instrument Society of America have a job to do in educating the instructors for these courses.

Now with those statements of general policy, with which I am wholeheartedly in agreement, I am going to indicate some ideas of my own. Mention was made this morning (although not in exactly the same words that I am going to use) that there are two types of information which we generally present in our engineering college program. The first type has to do with fundamental physical facts and the ability to use them in solving physical problems. This we may call the science of engineering.

Many of you have been talking not about the science of engineering but about the *art* of engineering, and the art of instrumentation engineering specifically. That is different.

The art of engineering requires some knowledge of manufacturing methods; it requires some knowledge of materials which are available; it requires some knowledge of the kind of products that you can buy down on Radio Row or other such place in starting to set up a project on instrumentation. That is the art of engineering.

These two are not unrelated, and it is usually necessary to know something of the art of engineering in order to get good practice in the science of engineering. When I first entered teaching I had been doing power-plant work and I was imbued with the idea that I was going to teach some of the concepts of selection of equipment in power-plant operation. I went in to the class and began to talk about some of these things and, toward the end of the hour, one of the students timidly raised his hand and asked, "What is a hot well pump?" Everything that I had said meant nothing, because the students didn't know the terms I was using. So I had to take about two months off to teach the nomenclature and terminology of power plants. After that I had a few weeks to try to meet the objectives which I had set up.

Now you can't do an adequate job in the science of engineering without some knowledge of the art of engineering. Instrumentation and control provide a very fertile source of illustrations of the application of the science of engineering which require a minimum background in the art of engineering. Therefore, it seems to me that it is an unusually desirable method of presenting these fundamental concepts which we have all agreed are so important.

The fact that instrumentation is so important commercially and such a live subject all over the country is not a disadvantage. The students will tend to eat it up, I believe. Certainly, therefore, the increase in emphasis on instrumentation in engineering instruction seems to be a logical conclusion.

One obvious solution is the elective course: Such a course can be used to develop further understanding of fundamental concepts of physics at the same time that you are building up some concepts of the art of instrumentation; but this course should not be given in the electrical department alone, nor should it be given in the chemical department alone, nor the mechanical. It should be a coöperative program of the several departments. I can't imagine *very many* chemical engineers being qualified to give an adequate presentation of electronic metering procedures, neither can I conceive of the man who is a "wiz" on electronic metering being able to have the feel of the application of that

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For DISCUSSION of this paper see pages 824-836.

branch of instrumentation to process engineering. So I think that coöperation is needed.

The less obvious, and the more difficult method—possibly the better if it is possible to achieve—is to place some emphasis on instrumentation in all courses. That is, to utilize illustrations of instrumentation in the mathematics course, in the direct-current circuits course, in the alternating-current circuits course, in the process engineering course, and in the materials course—in all of those. But here you have increased your problem, because *every man that uses those illustrations will have to understand instrumentation.*

Finally, some industries probably will need specialists in instrumentation; and I agree with the speakers this morning that for this specialization there should be a graduate program. It may be possible, it may even be desirable, that the undergraduate program be pointed somewhat toward the graduate program, but in general I don't think specialization in instrumentation should be included in anything less than a five-year program.

The question is, what to do about it? I am going to make some suggestions which I hope the Instrument Society of America will not feel are presumptuous on my part. I think the Instrument Society of America has a grand opportunity, and I am sure that you are going to use it.

Let me preface my suggestions by saying that several years ago I suggested that the curriculum in the Army specialized training program in electrical engineering should include a course on servomechanisms; immediately this produced a flood of letters into the office, "What is servomechanism?" Now then, M.I.T. had already established a procedure for setting up a program for instruction in ultra-high frequency techniques; they had called in representatives of some 75 engineering colleges to a two weeks' session at the Institute, and they said, "We know that the government is going to need a lot of men trained in ultra-high frequency techniques." (People weren't using the word radar in those days). "Heretofore it has been entirely a graduate program. Now it has to be taught in the undergraduate program. How are we going to do it?" Dr. W. L. Barrow and his associates, along with these teachers from some 75 colleges, developed in those two weeks a curriculum in ultra-high frequency techniques that was a tremendous help in making effective the program of electronic instrumentation —radar—which permitted our armed forces to really do a job.

When we who were organizing the engineering curriculum of the Army Specialized Training Program came to servomechanisms we said: "That method is good, we'll use it again," and so we called on Dr. Brown and Mr. Campbell to set up a similar program. After a week we came out with a course on servomechanisms. It wasn't perfect; everybody didn't follow it to the letter; but every one was giving their students something of that interest in dynamics, that Dr. Brown described as "putting a gleam in their eye" this morning.

Now, gentlemen, I don't see why you can't do that same thing with instrumentation. I don't believe there are more than a dozen college professors in the United States who are competent to set up a program of instrumentation, a real instrumentation course. The rest of them won't do it, *you* will have to do it for them; or you will have to get them together and do it coöperatively —which I think is probably better.

You should get a large group together, but you don't work in large groups; you break up in committees: You have a committee on equipment, another on process instrumentation, another on electronic instrumentation, and another on this, that and the other thing, Professor Brown can tell you all about it. It seems to me that this is the kind of thing which the Instrument Society of America can do, and when you do it you will get instruments and instrument courses into the curricula—and in my opinion not before.

When it comes to getting the illustrations of instrumentation to the professors who are teaching a course in mathematics, or in d-c. circuits or a-c. circuits, or some other specialty, you have still a different problem—an even more difficult problem. In this case you must provide those illustrations. You must provide them in detail. You must supply them regularly, must keep pegging at it. The professors are just as pushed for time as most good engineers—and when they find a good illustration already set up for them, they will certainly make use of it.

It is up to you gentlemen to supply these illustrations, because you know what they are—the professors don't.

It may be that the instrument companies, General Electric included, will have to work with you in setting up the necessary equipment to do this job; if and when a real course is outlined. I don't think the instrument companies will have too much difficulty in that.

Gentlemen, I think that if you do these things you will be surprised at the progress you will make in instrumentation instruction in the colleges. You have a grand opportunity and I am confident that you are going to make use of it.

Fitting Instrumentology into the College Curriculum

By C. O. FAIRCHILD, Director of Research, C. J. Tagliabue Div., Brooklyn, N. Y.

WHAT is "instrumentology"? I have chosen this word because to me instrumentation has always meant the application of instruments to the control of industrial processes and manufacturing techniques, and has not included methods of measurement, distinct from the particular instruments used to carry them out, theories of design of instruments themselves, distinct from what they are to be used for, nor theories of instrument performance, distinct from methods of measurements. An instrument engineer should know a good deal about methods of measurements and theories of instrument design and performance in order to be successful in the instrumentation of a process. "Instrumentology" was recently proposed by Paul E. Klopsteg[1] as a contraction of "*Instrumental Technology.*"

All of science is based on experimental proofs of theories by means of measurements with instruments, and all of engineering makes use of quantitative information based on established standards of measurement, and the techniques of instrumentology. I am not laboring to broaden the meaning of this word. I am merely facing the unavoidable fact that instrumentology pervades all of science and technology. Years ago there were established in various countries many bureaus of "weights and measures" where the science of "metrology" was applied. Metrology has meant the measurement of length (and volume), mass and time, and the establishment of standards for these quantities, and the word is seldom used to signify the science of measurement. Just as the National Bureau of Standards with its exceedingly diverse activities has grown from the Bureau of Weights and Measures, just so has instrumentology grown to become a vast and complex assemblage of sciences, technologies and mostly applied arts, which is apt to dismay us in that aspect.

But we should be no more dismayed by this picture than we are by the vastness of applied physics or chemistry. We should direct our attention rather to the recognition and establishment of instrumentology as a technology having its own well-established general principles of measurements and

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For DISCUSSION of this paper see pages 824-836.

1. *Science*, Vol. 101, 1945, page 571.

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SOME OF THE SPEAKERS FROM UNIVERSITY SCIENCE AND ENGINEERING DEPARTMENTS

control and vast fields of application. There *is* a science of instrumentology, both theoretical and applied. Perhaps the term Metrology is more acceptable as meaning *theory of measurements*, but we are concerned particularly with the general and pervasive nature of instrumentology in order to resolve the problems of fitting it into a curriculum. We are supported indirectly in our thinking of instrumentology as a definable applied science by Klopsteg[1] who describes research laboratories of instrumentology in a graduate college, whose work would constitute "the application of science to science itself." Klopsteg's long experience both as business man and promoter of science education, has led him to emphasize the importance of instrumentology in the sciences, and the occasional added impetus given to progress in a science by the development of a new instrument for measurement or observation.

How can so complex a technology be fitted into a curriculum? Unless we establish a separate major course in it leading perhaps to the degree of Instrument Engineer, we cannot hope to compact it into its own niche. But first we must consider what is wanted and needed today by industry in the recruit engineer. Homer L. Dodge[2] said a few years ago, that "industry is realizing that it must go back of engineering to the parent science, physics." This is a brief statement of a broad concept, the dominant note of which appears to be simply that engineers are found not to be trained adequately in the fundamentals, and where these fit into the complex fabrics of the applied sciences—engineering. Gustav Egloff has often stated his preference for men trained in the fundamentals, whom he would teach the special techniques and factual information of his own interests. Although industry is now faced with a serious shortage of trained men in almost all fields of science and engineering, nevertheless I would suggest that colleges aim to supply the men well trained in the fundamentals and leave it to vocational schools to supply the needed technicians. This means that the *ultimate* aim of the college should be to establish a course or courses that will make *an instrument engineer well trained in the fundamentals*. As usual these fundamentals should be mathematics, physics, and chemistry, with stress for the instrument engineer on advanced mechanics, thermodynamics, mechanical vibration, alternating currents, wave motion and heat transfer—and the theories of measurement as a special short course. Such a *major course* should also include short courses in the general theories of instrument design and performance, and automatic control.

While the major course is being planned and until it is set up, the various branches of instrumentology should be taught in conjunction with the topics to which they are naturally related. Here are examples: (1) The measurement of mechanical properties with strength of materials; (2) temperature measurement with heat, thermodynamics and all topics involving thermal processes; (3) flow measurement with fluid dynamics; (4) microscopy with metallography, petrography and microchemistry. We soon find, however, in attempting such correlation, that there are innumerable cases of serious overlapping. No doubt temperature measurement is the most troublesome case and as to electrical measurements we must distinguish between instruments for measuring electrical quantities and those using electrical methods incidentally. There are two primary answers to this problem of overlapping interests. One is the complete separation of each branch of instrumentology, such as pyrometry or electrical measurements, and the other is the complete weaving in or absorption of instrumentology into the curriculum. This absorption simply means being more instrument-minded, using more instruments in all instruction, and teaching more about the theories, methods and errors of measurement and the relation of every measurement to a theory and a standard. Instruments should be used as much as possible for demonstrations accompanying lectures, and profusely in all laboratory courses. Students should be taught from the beginning that measurements with a thermometer, ruler, voltmeter, or chemical balance are *always wrong*. They should be taught that a thermometer always gives the wrong answer not only because of the emergent stem, but because it has not been calibrated exactly right, and because it will never be at exactly the same temperature as the thing being measured. The notorious over-confidence of students in the accuracy of experiments should not be condoned to avoid loss of interest, but should be explained as pride in precision, with the accompanying explanation that a determination of the accuracy of the results usually requires a separate series of experiments. I do believe that the relation of all measurements to standards, the physical and chemical constants, and the methods of interpolation for establishing measuring scales, cannot be overstressed. Instruction instruments should be selected for their simplicity and theory of design, and the student should be required to learn how to obtain the best results with each instrument used. That is, he should learn how to calibrate it, and relate his calibration to a standard, why he used the method of measurement, and what conditions (such as temperature of the instrument itself) should be watched. Wherever it is practicable, at least two instruments—employing different methods—should be used for the same measurement. This is important because it is the best way to teach the skepticism[3] of instrument readings that must become second nature to the experimenter.

To be sure, there are many factors that interfere with the absorption of instrumentology, the principal one being the indirectness of so many methods of indication, and the empirical nature of the conversion so often found in electrical instruments for measuring non-electrical quantities. The use of such instruments for demonstration may be too distracting from the related topic.

Probably the first branch of instrumentology to be taught in a separate course was pyrometry, which has been taught in scores of colleges for the past twenty years, and in many instances has included thermometry. The course is found sometimes in the department of physics, and sometimes in the departments of electrical, mechanical or metallurgical engineering. This is immaterial until the time comes when there

2. "Physics in Industry," American Institute of Physics, New York, 1937; page 235.

3. R. B. Sosman, in "Temperature, Its Measurement and Control in Science and Industry," Reinhold Publishing Co., New York, 1941; page 327.

are enough separate courses established to group them under instrumentology. I would suggest that the courses in pyrometry and thermometry should include more theory of heat transfer and of automatic control. Perhaps automatic control is best taught as a separate subject to include the principal variables such as temperature, pressure and flow. I might suggest that courses in industrial electronics and electrical control eventually be included in modified major courses in instrumentology, because of the close relationship of instruments to the principal machines and devices used in these two fields.

Separate courses should be planned for many other important branches of instrumentology, not only where automatic instruments are now available for plant and factory control, such as for temperature, flow, pressure, liquid level, speed and position, pH, humidity, weighing, and various properties of products, but also in the control and research laboratories for mechanical and electrical testing, spectrography, colorimetery, metallography, microscopy, including electronic, polarimetry, and x-ray analysis. Merely listing these reveals that instrument engineers will have to specialize, and we shall begin to wonder just how much difference there can be between an instrument engineer and some other engineer—or perhaps I should say some other technologist.

To a large extent we have the old story of eternal vigilance, and adjustment of the curriculum to meet the demands of science and industry. These adjustments should include both the establishment of separate courses to meet the demands as they become apparent, and the more thorough *instrumentation of the curriculum as a whole*, in lecture room as well as laboratory, beginning in the first year. Only by pursuing both of these methods, can the requirements of the small plant for a man of broad training in science and instrumentology and those of the large companies with completely staffed laboratories, be met.

Much work is ahead of us which has to be done before instrumentology can be adequately handled by the university instead of having to be garnered piecemeal from scattered sources, most of which are descriptive treatments of applied arts and wholly lacking in formal analytical presentations which are necessary to assimilation into the curriculum. There can always be some hope of absorbing analytical instrumentology but curricula are too crowded to include much descriptive matter. To be sure the young graduate has to understand the language currently used in industry, but this language has to be explained to him in classroom language of the basic sciences, in order that he may be able to continue to use his early training and also be able to coördinate and identify the principles common to different fields. It would be fine if the first principles of damped periodic motion and forced vibration could be taught once for students in different courses so that, for example, "negative feed-back" and "cathode follower" in electronics could be identified with "automatic control" and "self-regulation" in pyrometry or control engineering—and "resonance" would always be recognized wherever found.

Let us hope that the Instrument Society of America will be successful in its endeavors to bring men together from many different fields of science and engineering, coördinate the fundamentals of instrumentology, and help fit them into the university's crowded courses by encouraging the writing of analytical texts which are suitable aids for the instrumentation of the curriculum.

Since I prepared these brief notes, *Mechanical Engineering* for October has come to hand, in which Professor Theodore von Karman writes under the title, "Atomic Engineering." I am urged to quote as follows: ". . . do we give today to the future engineer enough fundamental knowledge? . . . Is there something wrong in our engineering education? I am afraid there is . . . We try to train engineers so that the employer can use them almost immediately after graduation from school . . . We are reluctant to present the fundamentals of physics and chemistry as a living science full of question marks and changing concepts." He writes of the error of training the type of practical engineer who "perpetuates the errors of his predecessors" and finally concludes: "I am convinced that the knowledge of the deepest origins and also the limitations of the principles does not handicap a person in their practical application; as a matter of fact, real knowledge makes the application easier and safer."

Education in Instrumentation for the Process Industries

By DONALD J. BERGMAN, Engineering & Development Dep't, Universal Oil Products Co., Chicago, Ill.

I SHOULD feel hesitant about advising a group of modern educators and students on the subject of education. Two years ago I attended a meeting of the Society for the Promotion of Engineering Education and heard a speaker discuss Engineering Education of the Past. He divided his subject into two periods: the previous twenty-five years, and prior to that—to the dawn of time. I realize my deficiencies when I consider that my connection with formal engineering education ceased in the antediluvean era.

Nevertheless here are some suggestions as to the kind of graduate I should like to get from a school to start training along specific lines for a control engineer.

I would point out that this man is not to be a designer of instruments, but rather one to apply them to processes.

Webster's Unabridged Dictionary lists 56 varieties of engineers starting with Administrative and ending with Water Supply. Special developments during the war alone could probably double that number; news articles have recently referred to the "atomic engineer." Too often the use of an adjective in connection with the word *engineer* represents one whose range is limited to a narrow field. I would not propose the term *control engineer* to represent one who knows little outside of the specification and adjustment of control instruments. That would be an instrument man.

Since, for the present, much of the solution of control problems comes by way of art or intuition, it is probable that, more than the average graduate in other branches of engineering, he who follows the field of control equipment must needs be born under some peculiar set of stars which direct inclinations. Hence, a screening or aptitude test for the selection of embryonic control engineers would be of help to the individual and to industry at large. However, such preselection smacks of regimentation — and schools and industry must be prepared to weed out the poor and advance the good in this field as in others.

A large number of the varieties of engineering credited with specific names have control problems, requiring as many types of control engineers. Consequently, a closely specialized training in any one branch should be avoided. On the other hand, the fundamentals of engineering and mathematics are no different from those required for a good electrical, mechanical or chemical engineer. These fundamentals change little with time. My high-school freshman son informs me that my algebra homework compares favorably with that of his fellow-students.

As with any other branch of engineering, the time available in school is so short, and the chance so small that a student follows exactly the line of work he selected in school, that it appears most feasible to cover only fundamentals of control during undergradu-

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For DISCUSSION of this paper see pages 824-826.

ate days, and provide additional mathematics, physics and electronics for an advanced degree.

Certainly there should be no differentiation in the first two years of college. Beyond that point in the Junior and Senior years some of the "musts" for a control engineer come to the fore. These would be—

1. Mathematics through differential equations.

2. Organic and Physical Chemistry, Stoichiometry, and Thermodynamics.

3. Chemical Engineering, covering unit processes of heat transfer, heat balances, distillation, drying, fluid flow, etc.

4. Higher electrical physics and electrical engineering theory and laboratory work.

In connection with the subject of mathematics for the engineer in general, stress should be laid upon the applications in engineering. Experience indicates that pure mathematics is largely distasteful to the type of mind attracted to engineering. Problems which are met in industry are never stated in mathematical form, but must always be translated to that form from physical statements or facts. Practice in making such translation from high-school algebra onwards is of utmost value to the student, who is aided in remembering the mathematics by the association with the physical problem through which it was presented.

Probably not over 10 percent of graduate engineers out of school five years can solve a simple problem in maxima or minima by calculus without referring to a text. Since control engineers are more likely to use their mathematical training in actual work, they should belong in this 10 percent group.

Because of the tremendous advance of chemical processes in present-day industry, the control engineer in order to prescribe proper treatment must be able to follow process variations, know the effect of pressure and temperature on reactions, and know the chemical and physical properties of substances or be able to predict them from correlating data. Accordingly, a wide range of chemistry and chemical engineering knowledge is required.

Many control problems have direct analogs in electric circuits and the mathematics of control engineering is very similar to that of alternating-current electricity. Hence, the electrical engineer's training in theory and laboratory work is essential. Tremendous advances in control systems through electronic circuits necessitate thorough grounding in this phase of electricity.

Probably in the last year there should be a course familiarizing the student with the theory and application of control instruments to process control, using as a text such a book as Smith's Elements of Control Engineering and involving enough laboratory work to bring out the physical meaning of throttling range, reset, lags, self-regulation and other terms common in the control engineer's vocabulary. If, in this course, the student can be taught that the term "level control" is a misnomer in the majority of cases and that the required operation is usually "flow control adjusted in accordance with level," he will be the gainer by several years. Surely he will have to learn this and other seeming paradoxes at some time in his career.

Criticism is frequently leveled at engineers because of lack of ability in self-expression. Correction calls for courses in public speaking and English. Some acquaintance with metallurgy and economics would certainly be of value.

Arrangements for attendance at one or more of the schools for instrument men maintained at the headquarters of several of the major instrument manufacturers will provide the student with a thorough familiarity with modern control instruments better than any possible laboratory work at school. Such a course might be taken following either the Junior or Senior years.

Only a few are fitted by basic inclination to qualify for this particular branch of engineering. Further, the number of openings in industry is small compared to the chemical, electrical and mechanical groups. Hence, vocational guidance through faculty advisers becomes of top-ranking importance.

A few inherent qualifications which point toward the making of a successful career as control engineer are:

1. Manual dexterity as evidenced by neatness, speed and accuracy of handling laboratory or shop equipment.

2. Facility in use of mathematics as indicated by grades received in the various courses in applied mathematics, such as strength of materials, thermodynamics, and chemical and electrical engineering.

3. Curiosity shown by individual initiative in researches or studies in connection with hobbies or other non-curricular activities. This is the kind of curiosity, which, coupled with keen observation to note a slightly unusual or unexpected result, has resulted in such discoveries as x-rays, radar and a host of others.

Perhaps it will be noted that in this outline of the education of a control engineer there is nothing that would not be of advantage to any top-notch "engineer." The small amount of specific control theory would definitely be of advantage to practically all chemical engineers, who should know enough of the principles of control to appreciate the effect of such equipment upon a process, and the requirements for satisfactory process control.

It is probable also that a five-year course is necessary in order to cover the work outlined. In this case, perhaps some graduate work leading to an advanced degree might be possible under one of the presently - recognized branches of engineering as a major. Along with such graduate work might come researches on problems supplied by instrument or control equipment manufacturers, and by industrial users of such equipment. Particular problems open to the graduate student would be the adaptation and development of new scientific tools for measurement and control of process work.

Undergraduate Preparation for the Field of Instrumentation

By J. C. MOUZON, Senior Physicist, Brown Instrument Co., Philadelphia, Pa.

AN instrument company may receive a letter which when exaggerated reads: "We have purchased a deluxe model of your atomic-powered multi-point recording electronic What Meter. Our office is located 20 miles from our plant. We now wish to record in our office on this one recorder the following: liquid level, liquid flow gas pressure, gas flow, temperature and humidity. We wish to transmit the signals from the plant to the office by radio Any suggestions that you may have which will assist us in carrying out the details of our plan will be sincerely appreciated." Such letters may be considered to represent progressive thought or just plain day-dreaming. Nevertheless, they must be taken seriously because they represent the sort of thing that is actually being done and because they indicate the trend of thinking. (A little more thinking before purchasing the multi-point recorder would have been profitable.)

Measurement and control in industrial processes are indeed becoming more and more complex. The attempts of this Conference to unravel some of the problems involved in the training of students is good evidence that college faculties are not entirely made up of dreamers.

It is of interest to note that 26 years ago three papers

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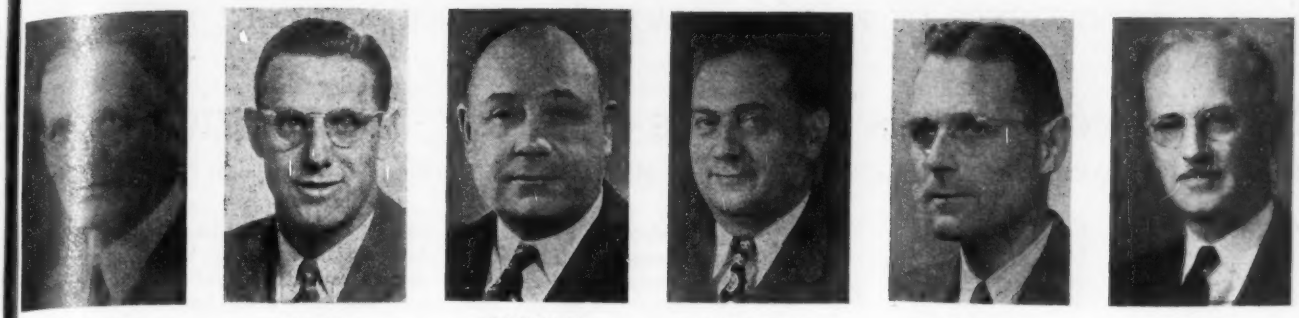

FAIRCHILD CAPELLE RICHMOND PARACHINI MOUZON HALL

SPEAKERS FROM SIX COMPANIES IN THE INSTRUMENT-MAKING INDUSTRY

were presented at the American Institute of Metallurgical Engineers on the teaching of pyrometry, calling attention to the need for metallurgical engineers with a sound background in the problems of temperature measurements. So we see that it is not novel for educators and industrialists to get together to discuss common problems.

It certainly is in order for engineering schools to consider alterations in their curricula which will take account of the increasing demands on the engineer in the field of instrumentation. The first progressive step has already been made in recognizing that a problem exists. The next steps should be in the direction of analyzing the problem carefully.

Let us consider a few points in this connection. Is it special book knowledge that we are missing, or is it a mode of thinking and analysis that we are failing to teach our students, or is it a combination?

The hurricane of 1938 on the East Coast cut off the power to many communities. In one home, the lady of the house found her maid vainly trying to use the electric stove. The maid was told that the power lines had been broken by the storm and that there was no electricity. Soon thereafter the maid plugged in the toaster—and again her mistress told her that there was no electricity. Then the maid was seen going from one base plug to the next attempting to get the vacuum cleaner to work. Her exasperated mistress said: "I told you the power was shut off—there is no electricity. Why do you keep plugging in the vacuum cleaner all over the house?" The maid replied: "I think there might be a little electricity left in one of these plugs."

In 1929 I was in charge of a laboratory course in optics. A graduate student who had majored in physics in one of our leading Eastern universities came to me and complained that his mercury arc was no good. I asked if he had it wired up correctly. He confidently replied that he had. On examining his layout I found the two terminals on the arc connected through a rheostat to the two terminals of an ammeter with nothing else in the circuit. Of course, the arc was no good, not to him.

Instrument sense was something neither the maid nor the graduate student had, but the maid *was thinking.*

Before adding new material to our course of study, let us examine our existing courses and the way in which we present them. If the method of presenting the existing material can be improved, the problem at hand may well be more than half solved. Then, if necessary, a minimum of new material may be added. There is not sufficient time to discuss this question at length so we can be specific only on one or two points. Consider the laboratory work. A good fraction of an engineer's time in college is spent in the laboratory. The tendency of the average student is to get the minimum amount of data in the minimum time without much thought about what he is doing. The tendency of too many professors is to have the experiments so set up as to permit the average student to collect his minimum amount of data quickly. For years, thoughtful men have persisted in insisting that the "why" for everything be examined. It is just as important for a graduate engineer to know "why" as it is for him to know how to do a specified thing. Too frequently we find men manufacturing things who say about a method or process, "Well, it works, so what's the difference?" We do not spend enough time teaching students what the difference is. If we did, we might not be so concerned about this problem we are now discussing.

What is there in the life of a student that makes him invariably slight mechanics if he is to be an electrical engineer? Why is it he thinks of himself as a specialist in his freshman year? His attitude is that he is going to be a practical electrical engineer so he need not be concerned with fundamental laws and definitions—that's theoretical. He goes through college and learns a variety of manipulations. He graduates and goes into industry. He finds himself lost for a while until he "gets his feet on the ground." He is frequently said to be too full of theories. Actually, he is too full of practice in doing special problems. He should have started with his feet on the ground as a freshman.

The competitive spirit among the various types of engineers need not be carried to the point of placing overemphasis on specialization. An attempt should be made to emphasize the fact that the successful engineer will be the one who can solve new problems—not just the problems he has been taught to solve in college. The tendency of so many people to turn our colleges into trade schools has grown at an alarming rate. This trend is one reason why a large percentage of college graduates have to learn to think after graduation. Too often the poor fellow cannot get over the fact that he is an expert and consequently thinks he should not have to do anything he was not specifically trained to do. Not only that, but he can't do anything else.

All of this is to the point as regards instrumentation in industry. At some time or other engineers will certainly be confronted with new instrumentation problems. An improvement in an old process or the setting up of a new process is surely going to involve some type of instrumentation. An intelligent approach to the problem requires first a determination of the variable which, when measured, will be correlated with the ultimate quality of the product. A little common sense usually will go a long way. So let us first make sure that our students are learning to use their heads as well as their slide rules and drawing instruments. Remember the average student in planning courses—and you will give the good student a break at the same time. (Of course, the good student will learn in spite of his professor.)

Now let us try to be a little more specific. As an example, take an electrical engineer who, let us say, will later want to study electronics. Teach him the fundamentals of electricity, not just $E=IR$, and not just the mathematical manipulation of complex numbers. When he studies an elementary indicating instrument in the laboratory see to it that he learns what it is—not just what the nameplate says it is. Don't make it necessary for his professor in electronics to have to teach electrical measurement all over again. *We have all the facilities at hand to enable the student to acquire instrument sense, so why not use them?*

My good friend, Dr. R. M. Sutton of Haverford College,

Continued on page 852

Servomechanisms Courses—Their Pedagogic Value

By DONALD P. CAMPBELL, Instructor, Electrical Eng'g Dept., Massachusetts Institute of Technology, Cambridge, Mass.

THE widespread use of precision instruments and of automatic-control devices and systems throughout industry and research today is almost incomprehensible. Furthermore, in our business and social lives we notice the gradual appearance of similar devices which not only expedite the work we do but which also increase our pleasure and well-being. The layman and the scientist find speculation upon future control applications fruitful because situations in everyday life can hardly be named where automatic control cannot be used effectively.

An educational problem calling for fertile creativeness and inventive thinking arises from this activity. Men demand to know what automatic control is, where it comes from and how to apply it to advantage. Likewise, man's accelerated interest in the art of automatic control, resulting directly from the war, causes him to seek quantitative information pertinent to the design and construction of automatic-control systems and instruments as a profession. An educational program which meets these collective needs of the control designer and the user in a manner that correlates basic engineering fundamentals has been given at M.I.T. under the direction of Professors H. L. Hazen and G. S. Brown. One or two other schools have offered similar programs, but the question must be answered, "Should more training of this type be inaugurated in our engineering schools and universities?" Care must be exercised when selecting the foundations upon which this educational phase of automatic-control engineering is to be built because we are attempting to establish pedagogical practices during a pioneering era in the science. However, a sound approach to this educational problem may satisfy the immediate need of training measuring-instrument and automatic-control personnel, and also influence future trends in engineering education.

An understanding of the gradual rise of the art of measurement and control explains the introduction and use of so many different types of equipment and apparatus for accomplishing particular automatic-control functions. New ideas and new types of equipment which became useful in the general engineering arts were rapidly adapted and incorporated into the automatic-control art. Resulting directly from this practice, we find that the equipment used today in the field of automatic-control consists of a heterogeneous conglomeration of mechanical, electrical, hydraulic, pneumatic, electronic, optical, pyrometric, and other types of elements and components. Although such diverse use of apparatus lends flexibility and general interest to the science, it confuses educational problems because *engineers cannot be trained specifically* to enter any *one* field of control when they graduate from technical schools. However, the possibility of using these varied elements as a means of cross-fertilizing the basic subjects of an engineering program is significant.

The educational problem associated with the measurement and automatic-control field is much broader than first glance will show, for one must consider what the objectives of the training are to be. Topnotch designers and theorists are needed; general engineering practitioners must be trained; and, finally, quasi-scientifically trained sales and maintenance personnel to mediate between the using public and the manufacturer or the theorist are needed. Obviously, no single university course can meet all of these needs because the scope of the training needed is too broad. However, the same training program in fundamentals used for process control groups can adequately meet the needs of naval fire-control and gunnery personnel, industrial-machine control personnel, aeronautical control personnel, and others who are concerned with vital and active *engineering* problems in automatic control. To do even this necessitates evaluating the education problem in terms of the fundamental similarities which exist among the diverse applications and upon these develop *a non-specialized method of instruction within a specialization.*

This plan is in direct agreement with the general philosophy of university education where the young engineer is taught fundamentals first and engineering practice is deferred until he enters professionally into industry. However, a modification of this basic philosophy for accomplishing its end-point is necessary because a thorough grounding in the fundamentals no longer constitutes sufficient graduate training or even undergraduate training. The student must be sent out into the world with confidence and a good common-sense ability for using the fundamentals to advantage.

The task is easier to cite than to accomplish, for the chaos existing in the average student's mind resulting from the unrelated manner in which fundamental theory courses are presented must be eliminated before formal instruction ceases. While laboratory courses are in general intended for this purpose, they alone cannot produce the desired over-all result. There seems to be need for a formal carefully-supervised course in the regular or the elective curriculum to provide the needed integration of fundamental theory. The responsibility of aiding the student in the manner described *cannot be relegated entirely to the university.* Industry often erroneously concludes that the student should be filled with specialized information upon leaving school, specifically able to immediately perform at a profit for the company he enters. A revision is needed here in favor of the student for he is now merely a mouthpiece or an automatic element in himself and, rather than becoming a progressive thinker, he is often thwarted and falls by the wayside. Recognizing the obligations placed upon both the university and industry, let us now consider how a program for training automatic-control engineers can be accomplished.

The science of automatic-control is based upon continuously controlling the behavior of a prescribed time-varying magnitude in accordance with some other predetermined variable which also may be time-varying. The object of performing the control is to make available a device which is capable of reasonably replacing a human operator ordinarily required to perform the task. Sometimes human physical limitations necessitate the use of automatic control; sometimes economic reasons dictate the policy, and often the complexity of the control to be accomplished exceeds the mental comprehension of a human. The type of apparatus chosen for automatic-control systems usually operates upon the fundamental principle of comparing the controlled performance of the time-varying magnitude with the desired magnitude in such a manner that the error or deviation which exists between the two actuates the controlling mechanism. The keynote of the entire science springs from this concept: automatic-control systems are inherently closed-loop dynamical systems.

Permit me to reiterate. *The science of automatic-control must be founded entirely upon the concept of studying the dynamical behavior of physical elements, physical systems, and combinations of physical systems, elements, and humans.* The starting-point for effective educational planning lies here but it must be carefully understood that the dynamics of which I speak is not pseudo-dynamics sometimes found

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in the elementary course of mechanics and physical sciences, but an all-inclusive dynamics aptly described by Sir Isaac Newton who once said, "There is only one science of mechanics—dynamics—and all studies of statics are special cases." Dynamics alone cannot serve as the foundation for building the educational program. Engineers live now in a world where practical, down-to-earth engineering translation of the physical theories must be accomplished by quantitative and not qualitative representation. Therefore, let us turn to the quantitative engineering approach and observe what it injects into the problem of engineering education.

The knowledge of how a process-control system operates in detail or how one performs some specialized function is not enough. The exact measure of how well the control performs must be known before the art is quantitative. Again let us refer into the past to the statement of a great scientist for substantiation, Lord Kelvin once remarked, "When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind . . ." An examination of the existing practices will show us the value of this approach. For example, the design of a control system entails a detailed knowledge of the gallons of fluid per second flowing through valves, the amount of mechanical motion of control valves, the instantaneous acceleration of motors under the influence of torques, the duration of oscillations excited in the closed-loop, the instantaneous power required to produce the required controlling action and the like. In every instance numerical values are necessary.

The prerequisite training elements which are essential if we are to produce men steeped in the philosophy of *quantitative dynamical engineering* are few but they are basic. First, the student should have a sound understanding of dynamics; Second, he should have a broad knowledge of mathematics specifically destined to be used as a tool of engineering application; Third, he should have a well-rounded understanding of the general engineering sciences including a knowledge of machinery, electricity, electronics, circuit theory, hydraulics, etc., from which useful information can be drawn as needed. Furthermore, a correlated understanding should exist between the theoretical training and the laboratory studies which parallel the theory. Although the burden placed upon the student is severe, here at last seems to be an engineering subject ideally suited for bringing the loose ends of the many components making up an engineer's background into one well-integrated whole.

Assuming that the student who wishes to enter automatic-control engineering has the necessary prerequisites, it now becomes necessary to prepare a complimentary program consisting of theory and laboratory courses to meet the established objectives. Theoretical study must be supported by confirmation in the laboratory of the principles expounded. A portion of the classroom work should be devoted to integrating the laboratory measurement problem with the theory. Also an effort should be made to refrain from the "easy-dose" coddling of the student in both the theory and the laboratory work. The student will resent being compelled to think for himself, but when these aims have been accomplished he will emerge not only a trained automatic-control engineer but a good sound-thinking student aggressively trained to follow an engineering career in any field.

Although many engineering courses can accomplish the general aims, which I have outlined, I should now like to describe to you in particular the program in Servomechanisms Theory offered at M.I.T. which I feel yields many special pedagogic values basic in the training of engineers and scientists, whatever particular profession they choose. The graduate courses in the Theory of Servomechanisms of which I speak comprise: (1) a course where the fundamentals of operation of closed-loop control systems are presented; (2) a later course dealing with the problem of servomechanism design and synthesis; (3) laboratory courses given in conjunction with the advanced theory course for the purpose of providing a quantitative approach to measurement and design and an appreciation of the fact that the system is a collection of instruments. The underlying philosophy of the graduate program is in essence that which has already been outlined; namely, a quantitative presentation of the theory of analysis and synthesis of closed-loop automatic-control systems from a dynamical point of view supported by laboratory confirmation.

To be certain that the conclusions derived from the coming discussions are valid, let us consider the status of the students entering these graduate servomechanisms courses, before proceeding with a description of the program itself. The students are typical engineering graduates of high caliber, standing perhaps in the top one-fifth of their class; they are electrical engineers, mechanical engineers, aeronautical engineers, etc. Although there are always certain exceptions, the group exhibits year after year the same weaknesses; namely, a vagueness in their fundamental understanding of dynamics; a lack of confidence when writing differential equations to represent physical systems; a lack of effectiveness in the use of the mathematics which they have learned. They have not integrated to any substantial degree the knowledge gained as an undergraduate such that they are capable of using information gained in one phase of their training to expedite work in another.

Deficiencies existing in the student's background must be offset in the first theory course if he is to be capable of appreciating the general overall problem of automatic-control to such an extent that he can enter successfully into the problem of design and synthesis in the advanced courses. The major part of our effort during the first semester is, therefore, directed toward creating in the student a feeling of genuine confidence in analyzing the behavior of control systems. This work divides into two sections: the first concerned with the establishment of the proper tools and techniques for performing analysis; the second, with the use of these tools and techniques on the fundamental control systems which constitute the backbone of the control engineer's working philosophy. Considerable attention is given to the problem of determining the transient response characteristics of closed-loop automatic-control systems to arbitrary external disturbances. The student is required to write the differential equation which expresses the behavior of various control systems. He is required to solve these equations and he is expected to be able to derive from the results numerical answers which the following typical questions will indicate:

How long will the transient persist in a particular control system if it is excited by a certain external disturbance?

What is the undamped natural angular frequency of oscillation of the control system?

How violent an oscillation can be tolerated in the performance of the control system in terms of the application?

Exactly how would you adjust the control-system constants to produce optimum dynamical performance?

These questions cannot be answered by qualitative study; they require quantitative data. This creates one of the many interesting pedagogical problems. If the student must be quantitative, he must be given an appreciation for the general magnitude of the mathematical quantities which describe the physical constants and variables of the equipment under study. (The students popularly refer to this part of their training as "acquiring ball park numbers" representative of the machinery and the systems with which they are dealing.)

Home problems are developed using typical figures to represent the physical constants of the equipment being studied. Classroom derivations are terminated with a "reduction to practice" attitude whenever possible. Actual components and control systems found in modern applications are brought into the classrooms and their operation is demonstrated, their constants measured, and a direct corre-

lation is made of the theory with these observations.

A typical classroom discussion may serve to establish the full extent of this line of reasoning. For instance, a motor rated at one-fourth horse-power is exhibited to the group. It runs at 3600 r.p.m. It is a shunt-field separately-excited motor wound for reversible operation. A discussion is built upon these questions:

What is a good round number for the moment of inertia for the rotor?

If the armature current is held constant, what is the stall-torque per ampere of current flowing in the field windings?

What is the ratio of the starting torque to the normal full-load running torque?

If a sudden voltage is applied to the field windings of the motor, what is the time required for the motor armature to reach substantially full speed in one direction or the other?

If the motor is geared to an inertia load member to be controlled, what is the net inertia of the system referred to that shaft where the load exists? Incidentally, how is the problem of impedance matching in the mechanical system handled compared to similar problems of impedance matching in electric circuit theory?

Never has any student felt that these questions are beneath his dignity and, as the work extends into the more advanced phases, it is gratifying to observe students making a rapid estimate of the weight of a motor for an aircraft application or condemning a blackboard discussion because they feel it does not contain enough down-to-earth facts.

The transient analysis approach to closed-loop control system analysis soon leads to a complicated and laborious program when we attempt to extend this mode of thinking to the more and more complicated systems which exist. New analytical tools for predicting and undertanding the dynamical behavior of the more complicated systems are found if we turn to the frequency-response studies of the communications engineering theory. Although the information gained is quite different from that found in the transient approach, there is a convenient readily-understandable correlation between the behavior of a control system excited by sinusoidally varying disturbances and one excited by certain other test disturbances. The method of analysis using sinusoidal disturbances depends upon observing the relationship between the controlled response of the system and the excitation causing this response in terms of a vector ratio. The magnitude of this ratio can be plotted as a function of the frequency of excitation and the phase angle between the vectors can be plotted against the same variable. Again a new type of thinking is demanded of the student, for one rarely finds engineers who will readily accept the fact that a mechanical system, a hydraulic system or a pneumatic system can be effectively studied by applying sinusoidally-varying disturbances to it, nor that its representation as a locus in the complex plane is practicable. Nevertheless, the student soon finds a definite correlation between the width of the frequency band where no pertinent resonance effects occur and in general transient behavior of the same system. It becomes clear that complicated control systems may have several independent modes of oscillation, some of which may exhibit predominant resonance effects while others either exhibit slight resonance tendencies or none at all.

Again the concept of "ball park numbers" is valuable. The student learns quickly that a mechanical system consisting of a heavy moving member will not oscillate at frequencies above a few cycles per second unless tremendous forces are applied to the body. Furthermore, when a system of this nature shows resonance in a manner not suitably damped, one can be almost certain that there will be ultimate destruction of the equipment.

The sinusoidal approach to the analysis problem leads to another interesting mode of thinking. The student soon begins to reason in terms of the transmission of data or information around the closed loop and to measure and estimate the perfection of the elements of the over-all system in terms of the amplification and the phase shift of the signal as it passes through the various components. Terminology is borrowed from the electronic and communication fields and he speaks of the "gain" or the "amplification" and the phase response of signals as a function of the frequency of the applied disturbance. When we glean this type of understanding among the students, the time has arrived for the presentation of the more profound tools facilitating the general problem of control-system synthesis.

A function theory approach to the general problem of representing the behavior of a dynamical system is introduced. The dynamic behavior of individual physical elements of a control system can be represented in terms of transfer functions and over-all systems can then be synthesized by properly combining the dynamical response of the separate components mathematically, or graphically. Furthermore, certain components not specifically defined can now be formulated in a clear and direct manner. Guesswork is eliminated and a sound-thinking embryo engineer emerges.

The theory course reaches its culmination at this point. The student finds that he has developed from a level where he was reticent to venture a prepared discussion or an analysis to a level where he desires to enter the laboratory and to build new devices along carefully-planned routes of scientific thinking.

The Servomechanisms Laboratory program commences with the simple one-afternoon type of experiment and broadens to the project type of experiment continuing for several weeks. Thus a wide variety of experimental possibilities permits the student first to gain a firm understanding in the fundamentals of quantitative measurement and later his study can be directed toward more extensive problems.

Elementary measurements made in the laboratory are concerned with the determination of the moment of inertia of motors and synchro armatures, the elastance of springs, the damping forces produced in oil-filled dashpots, the torque-shaped curves of prime movers (electric and hydraulic), and in general the static constants of typical control apparatus. Next, the student is required to measure the dynamic response for components of measuring instruments and of the simplest automatic-control systems. Often these measurements are purposely made without the use of elaborate measuring equipment because our experience has indicated that many measurements can be made in a simple and direct manner with hardly more equipment than can be comfortably carried in one's coat-pocket.

The advanced phase of laboratory work is planned once the student has mastered the fundamentals of measurement. Long-range projects are selected, preferably by the students, which necessitate careful theoretical analysis, correlating measurement, synthesis, partial or total construction and test of the completed apparatus. The scope of this type of work can be illustrated by considering some of the projects undertaken by the students: Closed-loop speed control systems for controlling automotive engines have been studied by using electrical-mechanical analog methods; components of automatic pilots for aircraft have been tested in an effort to improve the over-all system performance; an automatic tracking telescope has been considered; and a wide variety of less comprehensive problems has been studied. Frequently, these problems are extended to the scope of graduate theses.

Summarizing briefly, servomechanisms courses seem ideally suited for providing a correlation of engineering theories and ideas. Interesting and up-to-date subject-matter is used from almost all the engineering fields for presenting the theory in a quantitative manner. The students frequently return from industry to lend support to our hope that here, at least, is one place in the educational program where engineering training gets its cross-fertilization of subjects at a lively and sparkling tempo.

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A College Course for an Instrument Engineer

By S. R. BEITLER, Professor of Hydraulic Engineering, The Ohio State University, Columbus, O.

WHEN I came to the Conference yesterday I brought with me a prepared paper, but after listening to the discussions which took place in the meetings yesterday, I decided that the material which I had written had been presented by others in very much better form, and so I changed my plans and am going to tell about what we are doing at Ohio State on what we believe is a new variation of an old idea. This is to arrange a curriculum which will produce graduates well grounded in fundamental subjects, who will also have some training in specialized material.

The history of this experiment goes back about a year. At that time a meeting of the college faculty was called to discuss certain educational problems which had been emphasized by war conditions. The meeting finally developed into a discussion of how successful a job was being done by our present curricula in training the engineering student for the position which he was to fill. In general, this discussion brought out four basic ideas, all of which were more or less diverging from each other. These ideas were:

(1) The curricula as taught at present were satisfactory and that as the need arose for change this had been met by small changes in specific curricula items.

(2) The curricula were very much lacking in training in the fundamentals of engineering and science.

(3) The curricula were very much lacking in training in specialized engineering subjects.

(4) The curricula were very unsatisfactory because of the paucity of so-called "humanistic" or "broadening" subjects.

The majority of the faculty agreed to one of the last three conclusions and it was decided to make a study to determine what could be done to improve the curricula.

A special committee was set up to make this study and this committee worked hard and long, and eventually presented some plans which were approved by the faculty and which have gone into effect with the freshman class which entered in September.

In making the study, the engineering courses were first subdivided into three general classes: (1) the engineers for manufacturing industries, that is the mechanical, electrical and industrial engineering; (2) the engineers for chemical industries, chemical, metallurgical and ceramic engineering; and (3) construction industries, civil and mine engineers. Each of these groups was studied separately, and some conclusions were reached which applied to all while some applied to only the individual group. There is not time to discuss all of the problems encountered so that the following story applies in general to the problems of the first group, and specifically to the mechanical engineering curriculum.

The technical material in the curriculum was considered first. Going back to the things which were considered wrong, it will be noted that the two ideas about the technical material were exactly opposite: one that we had too little time spent on fundamentals and the other that too little time was put on specialties. These ideas came not only from the faculty but also from the employers and some of the graduates. A survey of the time available indicated that in quarter credit hours there were available about 216 hours for academic courses which were in addition to physical education, military and other similar courses. This assumption was based on the idea that the average student could put in about 58 hours a week on his school work.

The technical material to be taught I have classified under the following headings:

(1) Basic Fundamentals
(2) Engineering Fundamentals
(3) Languages
(4) Elementary Engineering
(5) Specialized Engineering

The basic fundamentals, mathematics, physics and chemistry, allowing the minimum amount of time which was thought to be necessary, would take up about 28 percent of this time. The engineering fundamentals for a mechanical engineer were thermodynamics and fluid flow, electrical engineering circuits, physical chemistry, mechanism, heat transfer, mechanics, materials and basic laboratory. The minimum necessary time for these was about 28 percent of the available time, so that the fundamentals would require 56 percent of the time available in a four-year course.

"Language" means the necessary methods of expressing himself which must be available to any engineer. There are two languages which every engineer must know thoroughly. These are English and drawing. These two subjects are just as fundamental to any engineering student as are the courses in physics and mathematics, and what was felt to be a minimum amount would take 12 percent of the time.

Elementary engineering courses are those which every student needs to have to illustrate the methods by which the fundamentals which he has been studying can be and have been used in engineering practice. These consist of courses in hydraulic machinery, steam power plants, internal-combustion engines, heating and ventilating, machine design, building design and shop practice. These courses as proposed would take about 19 percent of the available time.

When these were all added together it was found that about 87 percent of the total time available had been used and that there was still no time allotted for specialized engineering courses which many people thought were necessary. Nor had anything been done to satisfy that the last point raised in the criticism of the engineering courses, that is, lack of "humanistic" courses. The general feeling was that a student who would take an engineering course of this sort might be a good engineering machine, but that he would be a very poor citizen and that education should train for citizenship as well as for work. Then, if the student put in as much time as was contemplated in work on the required studies, he would have no time for recreation or even to read enough to keep up with the progress of the world.

With these facts facing us, two choices were available. These were:

(1) Leave out some of the fundamental material so as to add non-technical studies and specialized engineering subjects.

(2) Increase the length of the course so as to put in all of the material which was considered necessary.

After considerable discussion it was decided not to compromise but to increase the length of the program to five years and at the same time to reduce slightly the amount of work needed per week so as to give the student a little more leisure time.

This would give for a five-year program approximately 120 percent as much time available as in the four-year. This, on the basis of the four-year curricula, would enable us to use about 20 percent of the time for "humanistic" subjects and 14 percent was left for advanced engineering subjects. On the basis of the final five-year program then the division of time is about as follows:

1. Basic Fundamentals	23%
2. Engineering Fundamentals	24%
3. Languages	10%
4. Elementary Engineering	16%
5. Specialized Engineering	10%
6. "Humanistic" Subjects	17%

This arrangement seems to satisfy most of the criticisms made of engi-

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neering courses. However, it is subject to one new criticism, that it increases the time required in school for an engineering student. It was decided, however, that this was a good time to try this experiment—for two reasons: first, there were very few students now in school who would be discommoded by going through the transition period and, second, all indications pointed to a large over-supply of students in the near future so that, even if some prospects are frightened away by the increased time required, there still will be enough students to make the results of the experiment representative.

The carrying out of this program presented some problems which might be interesting and I shall discuss a couple of them. The first one was the determination of when the humanistic work should come. Since the Humanistic and Fundamental courses represent more than two years' work, the proposal was made that the program of the medical and dental professions be followed—that is, that a two-year course in pre-engineering be set up in the College of Arts to be followed by the professional courses. The other proposal was to intersperse these non-technical through the five years along with the technical subjects. The second method was decided upon for two reasons:

First, the average student when he comes to the university is well sold on engineering and it was felt that the "esprit de corps" which this introduces in the younger students leads to better work, and that this would be lost if there was no direct connection with the engineering college and profession during these two years.

The second reason was the feeling that the humanistic courses would have more meaning if the student was more mature and better able to understand some of the problems discussed.

The other problem which I might mention is that of what degree to give the graduate from this course. The American student in our present mass education scheme looks on a diploma or a degree as his direct reward for work done, and has been brought up to expect that he will receive a high-school diploma at the end of twelve years of school and a bachelor's degree at the end of four years of college work. On our own campus, students in Arts or Commerce will receive a bachelor's degree at the end of four years of work in a program which requires a smaller number of hours. If the engineering student were given only a bachelor's degree at the end of five years we felt that we might be, under present conditions, penalizing the student who took this program. This matter was taken up with the Graduate School and an agreement was reached with them to permit any of the students in the engineering program who could meet the scholarship requirements of the Graduate School at the end of the third year to become candidates for the master's degree. If the special work given in the fourth and fifth years is of Graduate quality they will be awarded two degrees at the end of the fifth year: the bachelor's and the master's. Those who cannot meet these requirements will only receive the bachelor's degree, and no degrees will be awarded for four years of work.

There may be some question raised by what has been presented as to its connection with a course for an Instrument Engineer, but I believe that if the time allotted for Specialized Engineering courses were used for courses in Instrumentation, this course is almost ideal for this and, since these courses will be given to students with a good background and will be taught normally to small sections practically on the Graduate level, a course for instrument engineers could be put in as an option in mechanical engineering, if there is a demand for such a course.

This program, as worked out, may not fit other schools whose students have different training. Ohio State, like most midwestern State universities, is required by law to accept as a student any graduate of a recognized high school and, as a result, we have to give in college some of the courses which other schools require as entrance credits, so that it may be that a school with higher entrance requirements might not require so much time in the college itself, though the total time in school would be the same.

In closing, may I say that we feel that by the adoption of this program we will turn out better engineers with both fundamental and some specialized training and better and more rounded citizens and, while we know that this experiment has been tried before and failed, we feel that now is a good time for it to succeed.

Industrial Instrumentation for Chemical Engineering Students

By C. O. MILLER, Professor of Chemical Engineering, Case School of Applied Science, Cleveland, Ohio

IN 1941 the Department of Chemical Engineering at Case School of Applied Science sponsored a series of lectures on Industrial Instrumentation which was received very favorably by approximately two hundred persons representing more than forty different companies in the Cleveland area and also including a number of undergraduates. During the next two years, a series of war courses was offered in the evening division of the college. In this work, we had the very able assistance of W. E. Sachse, Engineer in charge of instruments for the Standard Oil Company of Ohio. Since that time I have offered a senior elective course in the college. From the experience gained and the mistakes made in these aforementioned courses, I should like to give a few of my impressions on the teaching of Instrumentation courses, especially those involved in the training of Chemical Engineers.

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Instrument Engineering *vs.* Process Control

First of all, the Chemical Engineer is interested in instruments solely from the standpoint of the user. To him instruments are tools which will help him toward his primary objective; namely, that of producing finished products from raw materials. It is, therefore, my opinion that instruction in Industrial Instrumentation should be divided into two separate parts, one which can be called Instrument Engineering and the other Industrial Process Control. Instrument Engineering should involve the design and fabrication of all parts of the system from the measuring element through the amplifying system, whether it be mechanical or electrical, to the recording system. It should concern itself with the operating characteristics of electronic relays, pilot valves, proportioning and reset mechanisms, control valves, as well as their assembly into the final completed instrument.

Process control, on the other hand, should attempt to answer the following questions:

(1) What variations in temperature, pressure, flow, etc., are permissible in the given process?

(2) What measuring elements are most suitable to measure these variations?

(3) Would an electrical, pneumatic or hydraulic control system be preferable for the particular system?

(4) Is proportioning or reset type of control necessary?

(5) Who makes this particular type of instrument?

It is understood, however, that both Instrument Engineering and Process Control should include a study of fundamentals of automatic control, including an analysis of the time lags involved, as well as a consideration of simple on-off control *vs.* proportioning and rate of proportioning control. However, only the former need concern itself with the mathematics of motion, such as equations representing the vibration of a damped galvanometer.

Needs of the Chemical Engineer

Let us turn now to the specific job of training a chemical engineer in the field of Instrumentation. Here we have three different types of jobs to consider: the production man, the development man, and the research man. In production we have one object, namely to produce the largest possible quantity of product having given specifications. Loss of time or of product due to instrument failure is one of the production man's chief headaches. Some chemical plants require that the shift foreman be familiar with the instruments in his particular section of the plant, because they do not wish to lose time by reason of such trivial reasons as a broken thermocouple, dead batteries in a potentiometer or a clogged air filter on a pneumatic controller. The instrument division is called only after a check has been made on such common difficulties as those mentioned above. Instrument companies could help by including with the instrument a small booklet on common "symptoms and cures" for instruments, to be used for training plant foremen. To summarize then, the production engineer should be able to diagnose instrument trouble, take care of minor repairs and know how and where one instrument may be replaced by a slightly different type of instrument which will keep the plant running. He should be able to check instrument installations on a new reactor and know how to shift from instrumental to manual control in case of necessity.

The development man has the job of taking a process from the laboratory through the pilot plant stage up to the full-scale plant. He must decide whether the process is to be operated batchwise or continuously, and determine optimum temperatures and pressures, as well as proper mixing speeds and feed rates. Here, in the pilot plant and semi-works, is the place to experiment with instruments as well. Although the volumes handled, and hence the storage lags, are somewhat different from the full-scale plant, yet a great deal of information can be obtained on installation and valve sizing in the larger plant.

In research, we find that many of the instruments suitable for production are not applicable to the particular research job. For example, not long ago we had the job of controlling the temperature of an electrically-heated aluminum block within ¼ °C. This was necessary because we were studying the kinetics of a particular chemical reaction—and it is well-known that a chemical reaction doubles the speed every 10°C. Of three commercial instruments using thermocouples as the measuring elements, only one would maintain the desired control. In research, it is more often the case that no commercial instrument is available which will perform the desired task. It is up to the research man to use parts of instruments and make his own recording and controlling system. I have several examples to show you which I think will be of interest.

Fig. 1 shows the diagram of a home-made apparatus for determining the oxygen absorption in lubricating oil. It was our problem to measure the rate of oxygen absorption as well as the total volume of oxygen absorbed at a given temperature. The oxygen was circulated through the oil by means of a small pump consisting of a metal bellows

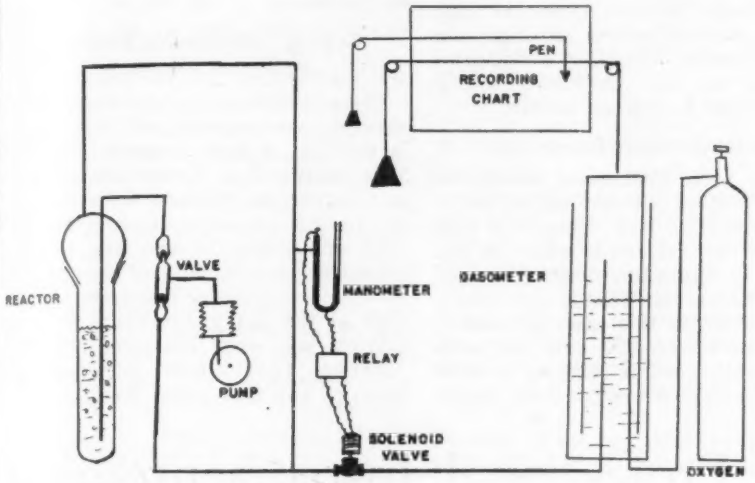

FIG 1.

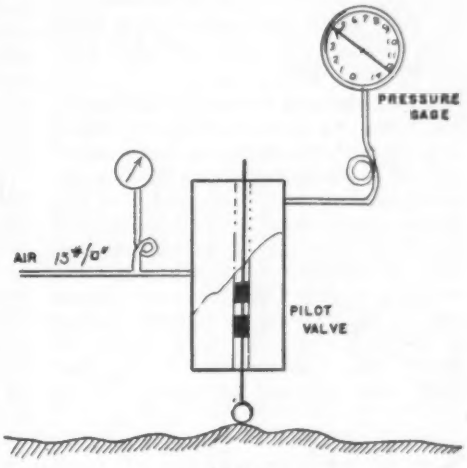

FIG. 3.

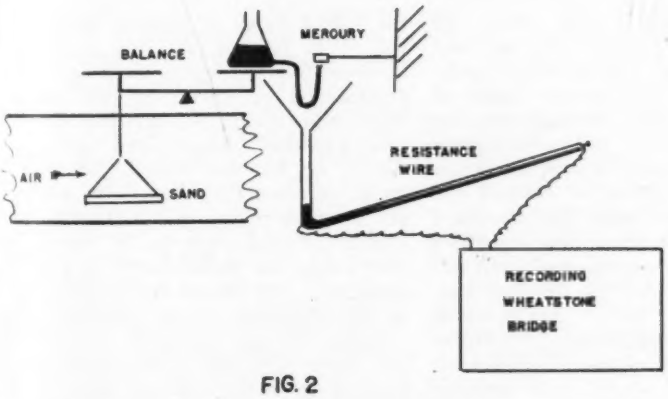

FIG. 2

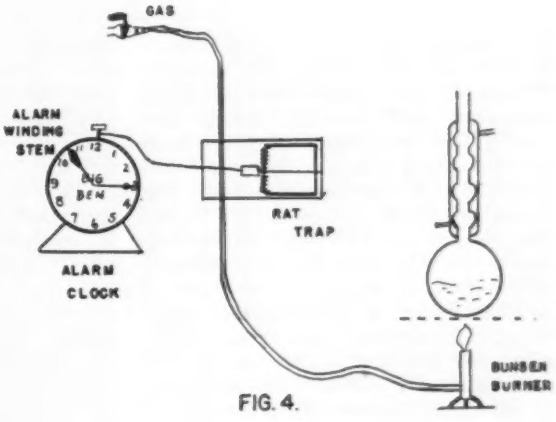

FIG. 4.

mounted on an eccentric shaft. As the oxygen was absorbed in the oil, the pressure in the system dropped until a mercury contact in the leg of a manometer would open a solenoid valve and allow more oxygen to enter the system. The oxygen was stored in a small gasometer whose inverted bell was 3 inches in diameter and 3 feet long. As the gasometer bell dropped, it pulled the recorder pen across a standard potentiometer recorder chart by means of a small chain. Since the chart was only one foot wide, an arrangement was made whereby a small weight would pull the pen-arm back to starting position after it reached one end of the chart. This was accomplished by means of a piece of spring metal attached to the pen, which would slip over a small stop wired to the chain and fall back to the next stop.

Fig. 2 shows a set-up for measuring and recording the rate of drying a fixed bed of sand by means of a stream of hot air. A small metal pan holding the sand was fastened to one pan of a trip balance by means of a thin wire through the dryer housing. As the sand became dry, the balance would tilt and allow mercury to flow from the other balance pan to an inclined manometer having a uniform resistance wire in the inclined arm. The progress of the mercury was recorded as change of resistance on a standard recording Wheatstone bridge.

Fig. 3 shows an ingenious use of a pilot valve and pressure gage to measure the roughness of a comparatively flat surface, each small move of the pilot valve stem being indicated or recorded by a change of pressure.

Numerous are the examples of the ingenuity of research men in devising automatic devices. Fascinating are their descriptions in scientific journals! . . . My favorite is the student's equipment for stopping a chemical reaction at a specified time—after he had left the lab to practice with the football squad. As shown in Fig. 4, his apparatus consists of one alarm clock, one piece of string and one large rat trap. At the set time, alarm clock rings, alarm winding stem turns, thereby winding string and springing rat trap on rubber tubing to cut off gas to Bunsen burner.

The Instrument Laboratory

In the past, instrument companies have maintained laboratories for training their service men. Here each man was given an instrument which he was required to completely dismantle, reassemble and adjust. This is ideal training. However, in this case, the man is being familiarized with only one make of instrument, and is required to work at the job eight hours per day. Such a procedure is not practical in the engineering school laboratory, for obvious reasons. Furthermore, we have found it to be extremely difficult to write a set of laboratory experiments on Instrumentation without having most of them degenerate into freshman physics experiments, such as the construction and calibration of a thermocouple. We believe, therefore, that the lecture and demonstration technique is best suited for this course. We plan to have an Instrument laboratory with semi-permanent set-ups for demonstrating various types of control and how each is affected by process lags. An inventory of spare parts, perhaps used ones, could be taken apart and reassembled in a short time.

Future Instrument Needs of Chemical Industry

Present indications are that future chemical development will be largely in the field of high-pressure processes. This means that special instruments will be needed. Already there is need for an instrument to measure and record small rates of gas flow at high pressures, that is, rates of the order of 0.1 ft.^{3} per minute. However, a brief visit at the Army Air Force show at Dayton last week convinced me that American instrument designers are equal to any task given them.

Specifications for the Professional Instrumentologist

By W. A. WILDHACK, National Bureau of Standards, Washington, D. C.

IN talking about educational specifications for professional personnel who will be engaged in work in instrument developments, design and testing such as is done in government laboratories, I want to follow a practice which is common in writing performance specifications under which complex and hard-to-make instruments are to be procured. The procedure is briefly this: First, you write down all of the items of performance which would characterize the ideal instrument for the particular job, as you envision it. No matter how impractical it seems, no matter if it appears to employ non-existent materials or a Buck Rogers anti-gravity belt, or if it appears to require three gears, a pressure reducer and an electron tube to occupy the same space and work interchangeably . . . No matter: you put it down—you get it off your chest. This document you label "*Tentative* Specifications for Gadget 106, Super-Duper Model." Then you present it, with many apologies, excuses, disclaimers, and hedges, to the suppliers who are to be responsible for making whatever you'll get. Then, in all probability, the suppliers will get a few things off *their* chests, too. Likely, these will concern bureaucratic visionaries, impractical theorists, the present state of taxes, the manpower shortage and the impossibility of two bodies occupying the same space; and how much better the plain Super Model of Gadget 106 is, anyhow, than what the Germans had in 1942. But when the amenities have been thus observed, they will admit the possibilities of a *few* improvements. Then the actual specifications are written to cover these possibilities and a few others as though they were an accomplished fact. And usually, after a few of the "bugs" are worked out of the experimental production, most of the compromise specifications are adequately met. This is one of the inspiring things that makes me a believer in progress—that men will strain their imaginations, cudgel their brains and worry out the solution to complex and obscure problems, to achieve the near impossible. . . .

But we are not now specifying an instrument, Gadget 106. We are here this week to discuss the specifications for "the man behind the instrument": the instrumentologist, the instrument engineer, the Instrumentician, the gadgeteer, if you like. Call him what you will, this man has a job to do. In the broad fields of science and technology, he has an inspiring job to do: to cross-fertilize every field with the crystallized experience of the others. This is a job for a lifetime. But in this war-mad, fear-crazed, poor-rich world, he has an urgent job and a great responsibility *today:* to accelerate the pace of the new industrial revolution of automaticity, to bring the world into the materialistic heaven of abundance and leisure before humanity, in its confusion, again attempts mass suicide. He has an even heavier job laid upon him, nay, even *forced* upon him, of which he will not soon be relieved in the years just ahead, that of sharpening the tools of war.

Many of you are educators. You are the suppliers, the fabricators of men, who fashion your product to our specifications. I want to list some tentative specifications for our ideal instrumentologist, and present them to you with apologies, reservations, disclaimers, and hedgings; quite confident that you will reject them at once, but equally confident that you will labor mightily to realize them, nonetheless.

I have no Federal Specifications to quote as a starting point. The Federal Government has been long engaged in the design, development, use, and testing of instruments, and now has a

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For DISCUSSION of this paper see pages 836-844.

VAN DER HOEVEN

OFFUTT

PUMPHREY

WHITE

YOUNG

SOME OF THE SPEAKERS FROM MANUFACTURING AND PUBLIC-UTILITY COMPANIES

score of instrument sections in various agencies. But, so far as I know, neither the Government as an employer, nor anyone of the various sections has ever considered what requirements should best be specified for professional personnel to be engaged on instrument work. And when it does, it will merely state that "the applicant shall have completed a major course in instrumentation in a recognized college or university"—thus putting the specifications back to the educators.

Let me at this point inject a disclaimer: This is in no sense an official statement of the Government or any branch thereof. I am a technical employee in one of the sections of one of the divisions of one of the bureaus of one of the departments of one of the branches of the United States Government—and that puts me a long way from top policy.

However, these specifications are not to be set arbitrarily by either bureaucrats or professors. *They are set by the nature of instrumentology itself.*

Instrumentology requires many things of its practitioners:

1. It requires a specialized knowledge of the measurement and control phases of all of the several fields of engineering.

2. It requires a working acquaintance with the fundamental laws and phenomena of every branch of physical science.

3. It calls for an intimate knowledge of mechanisms, and electrical, hydraulic, pneumatic, electronic, thermal and optical devices and instruments.

4. It requires a high level of analytical ability to analyze correctly problems of measurement or control or the operation of instruments, to gain physical understanding.

5. Beside physical understanding, it requires an ability to translate the physical facts into precise mathematical expression, and mathematical skill enough to gain a solution, a certainty of prediction.

6. Last, but far from least, it demands imagination. Imagination to recombine component devices and basic principles to evolve a new or better instrument. Imagination to see the common elements in new problems and to point new applications for existing instruments.

Such then, are the tentative requirements for the professional instrument specialist. They are obvious, perhaps to the point of being platitudes, and perhaps their desirability will be as generally accepted.

How can you provide the graduates with all these desirable attributes? It may appear that courses in design, hydraulics and electronics will have to be given in the same semester at the same hour and to the same person in order to fit in all of the course work that is implied.

Fortunately, most of the training in basic physics, mathematics and the various types of engineering can be adequately inculcated by exposing the student to courses already set up.

Classical physics, of course; but classical training alone is not sufficient. Many of the newer fields of radiation, nuclear physics, radioactivity, biophysics, medical physics, and astrophysics, all are full of special instruments and phenomena on which are based many instruments of widespread application. This is not to say that specialized courses in quantum mechanics or stellar dynamics are of any great utility to an instrumentologist; but survey courses emphasizing the principles and instrumentation of the experimental fields of physics would be extremely helpful in giving a broad acquaintance with instruments generally.

The added courses for specialized training could best start with a survey course in "Instruments: Principles of Operation and Applications." In scope, this course should include all *types* of scientific and industrial instruments, with adequate explanation and schematic diagrams illustrating the operation of typical examples. In method, it should relate each instrument to the basic laws of its own operation and through its qualitative performance to the laws involved in its various applications. For the major in instrumentology or the instrument engineer, such a survey course would be merely the first sample of his field. Further specialized courses in instrument theory, instrument design, automatic control oscillography, electronics, vibration, etc., are obviously in order to the extent that they can be administered without danger to the health or the student's extra-curricular activities.

While most will assent to the desirability of the suggested training, many will feel that it is impossible to fit so many added courses into a college curriculum. At this point, I remind you that the specifications at this stage are labeled "tentative." We may leave it for the educators to worry over what to chose, what to combine, what to reject, and still leave a little space and time for the specialized training in instruments. Perhaps a fifth year will be found necessary to do justice to the course.

However, if the need exists—and I am sure it does—for the college trained specialist in instruments, then it is safe to predict that within a decade more than a handful of the progressive universities and technological institutes will recognize the profession, as industry does already, and will grant degrees in Instrument Engineering. But even then, most of the design, uses, and specifications of instruments will continue to be done by engineers and physicists, who now wonder why their training did not include courses in instrumentation. Since a large part of the work of every engineer and physicist has to do with instruments—their design or use, it is important that they should be better acquainted with these modern tools. It is not enough that they are now given some training in the instruments peculiar to their fields. This is good, as far as it goes; certainly there are many electrical instruments adequately covered in electrical engineering, for instance. But instrumentation cannot be broken down into chemical instrumentation, electrical instrumentation, mechanical instrumentation because instrumentation combines both working principles and the applications from all fields. Instruments applied in chemical engineering, for instance, may be mechanical, electrical, hydraulic, optical or electronic in their basic design.

I submit, then, that the adequate training of any engineer will include, as a required subject, a course in instrumentation, wide in scope and fundamental in content. This might well be the same survey course in "Instruments: Theory of Operation and Applications," as suggested for an introductory course for the instrument specialist.

What Kind of Instruction a School Should Give on Instrumentation

By MALCOLM B. HALL, Supervisor of Training, The Foxboro Company, Foxboro, Mass.

ANY suggestion for an educational program below the level indicated by Dr. Campbell might seem to be an anticlimax, but there is a definite need for an educational program at the undergraduate level, as implied by the gentleman from the Tennessee Eastman Corporation. The title of this subject could be misleading as it might well apply to either the training schools operated by the instrument companies or to vocational schools. I am primarily interested in presenting this subject from the standpoint of undergraduate education in engineering schools.

The word "instruments" is a much-misunderstood word. To the medical profession it means scalpels, retractors, and specula. To the musician it means trombones, saxophones, and violins, and to the lawyer it means contracts and wills. It is unfortunate that there isn't a better word to describe the class of equipment which is responsible for this Conference. The instruments in which my company and contemporaries are interested are those mechanical or electrical mechanisms capable of detecting variations in process conditions and indicating, recording, or controlling these variables. I shall designate these as Industrial Instruments, as applied to Industrial Processes.

The tremendous development and production of materials for war has demonstrated definitely the importance of industrial instruments: the high-octane gasoline program and the synthetic rubber program could not have progressed to the unbelievable production rates in such a comparatively short period of time were it not for the types of industrial instruments available for these projects. It isn't surprising that the War Production Board placed the instrument industries high on the list to receive the necessary materials for production; nor is it surprising—when we consider the tremendous number of workers, skilled and technical, who have come in contact with industrial instruments for the first time—that there is an increasing demand for more knowledge of these instruments. As one who has been associated with the instrument industry for more than thirty years and who has been intimately associated with an instrument training program for the past eight years, I believe I may appropriate an expression from the well-known commentator Drew Pearson and say "I predict" that within ten years the majority of engineering schools will include a course in industrial instrumentation in their curricula.

Practically all of the major instrument companies have been conducting courses in the application and maintenance of their instruments for the benefit of their customers. As far as I know, all of these courses have been without cost to the customer, other than the transportation and living expenses of the customers' men sent to these courses. Speaking for my own company, since 1937 we have had over 450 customers' men from over 200 companies in our training courses and this does not include the work we have done with our own sales engineering and service personnel. These courses cover 84 hours and include lecture and bench work on the principles, construction and maintenance of the various measuring and automatic control systems within the scope of our product.

All of the instrument companies publish catalogs, engineering data, and carefully-prepared instructions on the application, installation and maintenance of their equipment—and yet, apparently, this material is not adequate. There is a definite lack of understanding of industrial instrument principles and mechanisms among those in industry who are responsible for their application to processes and their performance results. This can be rationalized to some extent by taking the position that it is the responsibility of instrument manufacturers to build instruments to meet process conditions and that the instrument company engineers should be able to acquire sufficient knowledge of an industrial process to recommend the correct instrumentation. We can't have any particular quarrel with that point of view because that is exactly the basis upon which the instrument companies have developed and expanded. They have established within their organization a staff of industry specialists. We grant that competition was the motivating force behind this policy but, where instrument applications were based on sound engineering principles, industrial progress inevitably followed and I again refer to the phenomenal development of the high-octane fuel and synthetic rubber programs.

Industry's need is for graduate engineers with a practical knowledge of industrial instruments and Instrumentation. The chemical engineer finds a field of activity in practically every industry. Mechanical and electrical engineers design and operate industrial equipment. These men should be equipped with a knowledge of instrumentation that will make it possible for them to develop new processes and improve present processes for greater efficiency. Because they are potential selectors of industrial instruments, they should know the basic principles of the various types of instruments; how they function; where, why and how they are applied. They should understand the theory and practice of instrument calibration. They should understand the angularity effect on calibration in link and lever type mechanisms and what is meant by force-friction ratio in these mechanisms. They should have the industrial instruments with which to work and in which to get their hands to acquire the feel and understanding of the mechanisms; and the laboratory experimental work should be set up to emphasize the characteristics and limitations of the instruments. These engineers should understand the functional differences between the various types of automatic control mechanisms and why they must be different to cover the broad field of application. These engineers should be exposed to the mathematics of automatic control and process reactions in order that the approach to process control problems can be on a quantitative basis. Perhaps this latter point should be placed in the field of graduate school education.

It may be interesting for the group assembled here to know that a practical course in industrial instrumentation has been set up within the Department of Chemical Engineering at Worcester Polytechnic Institute in Worcester, Massachusetts. At present the course is elective and open to chemical engineering seniors only. They have graduated two classes since the course was started; with another class in progress at present. It has been my privilege to work with John M. Petrie, Associate Professor in that department. Professor Petrie has spent considerable time at our plant, a large part of which was on actual bench work acquiring a knowledge of mechanisms, their characteristics, calibration and other fundamental points. The laboratory work is set up to permit the student to work with the mechanisms and to observe their performance on many types of processes.

What Worcester is doing may not be the last word in industrial instrument education, but it is a start in the right direction and I know that any of my listeners who may be interested in learning more about the course will get the fullest coöperation from Dr. E. D. Wilson, head of the Department of

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Presented at the Conference on Instrumentation And The University, Carnegie Institute of Technology, Pittsburgh, October 16-18, 1945.

For DISCUSSION of this paper see pages 836-844.

Chemical Engineering and from Professor Petrie and Dr. Graves, his assistants.

We believe that what industry needs most in the immediate future in the field of industrial instrumentation is graduate engineers with a practical knowledge of industrial instruments. With this knowledge the engineer will be prepared to improve and develop industrial equipment and processes, to interpret the instrument manufacturers' bulletins and instructions and to help his employer to protect a capital investment in instruments. If the Government stock of surplus instruments is made available to educational institutions, the program can be started immediately on a comparatively simple but sound basis. Instrument companies will still continue their training programs as the demand continues and they will gladly coöperate in any additional training or educational programs which may develop from this conference.

It will continue to be the responsibility of the instrument manufacturer to build instruments to meet process conditions.

Disposition of Surplus Industrial Instruments

By E. A. CAPELLE, Taylor Instrument Companies (formerly Chief Industrial Instrument Branch, WPB)

In a previous talk Professor Pollard stressed the needs of educational institutions for instruments for training purposes, and the monetary obstacles that exist in being able to procure them. The availability of these items as surplus equipment may be looked upon as a fortunate circumstance in connection with the present discussions on Instrumentation education.

The problem of disposing of surplus property in what might be termed the net national interest is a very difficult one. Considered in this respect are many factors which are undoubtedly apparent. Careful consideration must be given to all these factors by the government agencies responsible for disposal. Any actions that are taken have to be able to stand public scrutiny and Congressional inquiry. For this reason, the disposal of surplus equipment has been hedged with many safeguards.

Developments that are now taking place in Washington are cause for optimism on the part of educational and research institutions. The path is not entirely clear, and much work remains to be done to accomplish the objectives outlined by Professor Pollard. With the stimulus that can come from this Conference, a program can be developed which will be of mutual benefit to the national interest and to educational institutions.

To dispose of surplus equipment, a rather complex organization has been established. A brief outline of this setup and its functioning may provide a better understanding of the means by which educational institutions may acquire surplus instruments.

The Surplus Property Act of 1944 as passed by Congress establishes the Surplus Property Administration. Within the broad framework of the Act this agency establishes the policies for disposing of surplus property; directs the owning agencies (such as Army, Navy, Maritime Commission, etc.) as to the manner in which the surplus equipment is to be transferred to the disposal agencies; and directs that certain selected agencies act as disposal agencies. It is important to note that the Surplus Property Administration establishes the policies—which are expressed in the form of Regulations issued as warranted—and that the designated disposal agency is guided by these Regulations in its disposal operations.

The Reconstruction Finance Corporation has been designated the disposal agency for automatic process control equipment, sometimes also referred to as industrial instruments. Included in this grouping are pyrometers, tube-system temperature instruments, differential-pressure type flow instruments, liquid-level instruments, pressure instruments except gages, combustion controls, control valves, and regulators. My remarks are limited to measuring and control equipment of this type, as other classes of instruments are handled differently.

When an industrial instrument becomes surplus to the needs of the owning agency, it is declared available as such to the regional office of the R.F.C. Unless a regulation exists providing for specific disposal treatment, the R.F.C. office is to obtain a fair price for the particular item from the buyer.

Undoubtedly you are familiar with Regulation No. 2 which grants tax-supported institutions and state and local governments priority on available surpluses. If funds are available to purchase these at a fair price, presumably between 40% and 75% of original cost depending on condition, it would be wise to take advantage of this priority.

It is understood that a Regulation now being prepared will provide that surplus items may be disposed of for *nominal prices* in such manner as will benefit the national interest. This regulation will establish a means for making available to educational and research institutions surplus items similar to the manner in which Regulation No. 4 deals with surplus aircraft and accessories. The United States Office of Education is collaborating with the S.P.A. concerning this regulation, and may be instrumental in its operation. State and local educational agencies or boards will be called upon to equitably distribute available surpluses among the institutions in their respective areas. It is the hope and expectation of the S.P.A. that this program can be made effective in time to make items available for the second semester of this school year.

To assure continuance of this program and prompt effectuation, educational institutions should make known their need and desire for these industrial instruments, and the beneficial manner in which they can be used in training programs.

DISCUSSION

MAJOR BEHAR: In view of the urgency of the surplus instrument situation which Mr. Capelle has just described, it seems that this Conference should send a resolution to the Surplus Property Administration through the Office of Education. Therefore, Mr. Chairman, I move that this Conference send such a request, to be drafted chiefly by Mr. Capelle by virtue of his experience in Washington; the signatures not to include instrument manufacturers but to include educators who need instrumentation equipment for instructional purposes.

[Motion seconded.]

CHAIRMAN WILLIAMS: We have before us a motion which implies that we should appoint a committee to prepare a draft, with the assistance of Mr. Capelle, and that we should include signers primarily representative of educational organizations. Is there any discussion?

A MEMBER: I can't speak for anyone but myself as a representative of educational institutions, but I would like to see that presented to Washington as the opinion of the Conference, not educators alone, because one of the little touchy things involved is that manufacturers in general do not like to have their equipment put out on the market without cost. If it is the opinion of the manufacturers, the users of industrial equipment, *and* the universities, that it is of mutual benefit to have this surplus going to the universities, it would be the strongest recommendation, the educators being the weakest part.

MAJOR BEHAR: I didn't imply action by educators independently of this Conference. The request will come from "The I.S.A.-C.I.T. Conference on Instrumentation and the University,"

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representing all occupational groups concerned.

CHAIRMAN WILLIAMS: As I see it, the point is whether the signers should include manufacturers.

MR. HALL: (Foxboro Co.): I think I may speak for the instrument industry in saying that the industry would like to have this equipment made available to educational institutions at a nominal price or no price at all, because the instrument industry is going to be called upon to donate equipment to the educational institutions otherwise.

MR. SPERRY (President I.S.A.): I don't think there is any argument on the signing. Later on, when the I.S.A. meets, we will take up the question of amplifying that resolution and not only that, but push the thing, because while the resolution is always helpful, it helps to keep after it and hammer the thing home. It would be to everybody's advantage that they be given it, free of charge if possible.

MR. PIGOTT (Gulf Research & Development Co.): I think perhaps we can simplify this situation by amending the motion to empower the Chair to appoint a committee to draw up a resolution to suit the ideas expressed. It would have to be done today before the Conference closes.

CHAIRMAN WILLIAMS: How does that suit the maker of the motion?

MAJOR BEHAR: That is the sense of the original motion.

A MEMBER: It has to be done quickly, because the new rule is to go into effect the first of November.

MR. CAPELLE: I was down to Washington on Monday and Tuesday of this week, and the draft of the new regulation is in the hands of the lawyers. If they can get it out it will become effective the first of November, but I am cautious about making predictions.

The question of the attitude of the instrument industry has been raised. Mr. Hall has commented on that and I can say, after having conferred with the manufacturers, that they are agreeable that this surplus equipment be granted in a feasible manner to educational institutions. It is my suggestion that as recipients of this equipment, educational institutions express their attitude and desire for available instruments.

A MEMBER: If I may identify myself as a member of the group that is going to finally benefit from all this, the user, I would like to add my affirmation to that expressed by the educational institutions and the instrument manufacturers. In the long run the user industries are going to be benefited by better education.

CHAIRMAN WILLIAMS: We have a motion, and if there is no further discussion we can put it to a vote.

[The motion was carried unanimously.]

CHAIRMAN WILLIAMS: Carried, and we have a committee to be appointed. I appoint Mr. Capelle as representing the know-how, Professor Beitler as representing the educators, and Mr. Darnell of the I.S.A.

PROFESSOR BEITLER (Ohio State University): I don't know how many of you are familiar with the differentiation between surplus and excess property. Under one of the purchasing regulations of the Army, it is permitted to donate excess and salvage material to tax-supported schools which give preinduction training. The material is labeled "excess" and is Army property and is available for a short time before it is declared surplus. In practice, the Ordnance has been very fair in donating material which they own and which may be useful for educational purposes. However, it is usually up to the school to locate this material. This particular program is scheduled to end on November 1.

A MEMBER: Can you do that through the local Ordnance office?

PROFESSOR BEITLER: Through the Pre-Induction Training Branch of the local Service Command; they are the ones who normally must approve the application. The Fifth Service Command material is handled directly or indirectly through a state-appointed officer in each state, who approves the application. But the work of locating it has been done by the institutions and, as soon as this new regulation of the Surplus Property Board comes out, the excess property distribution of it will probably be stopped.

CHAIRMAN WILLIAMS: I might say, in amplification of Professor Beitler's remarks, that we have had the same experience, although we have not located any of this. We have been definitely told that if any Ordnance, Signal Corps or other equipment, which is now excess and which has not been declared to the Reconstruction Finance Corporation, is located and requested, it will be given free of charge. There are various methods of procedure for finding out what and where it is, and the only thing I can suggest is that interested educational institutions prompt their alumni at these companies to tip them off that such equipment is excess and is about to be declared surplus.

A MEMBER: Just before I left for this conference, we had succeeded in locating some 100 sets of B-29 turrets with associated computers and controls, which might tie in very satisfactorily with laboratory work on servomechanisms. We were working with the Signal Corps and the Army Air Corps to arrange for that equipment to be made available on a scrap value, so that our company's Educational Fund could purchase it as a gift to the schools.

PROFESSOR BROWN (M.I.T.): Thank you for making that remark. I would like to mention that M.I.T. has been approached by the Sperry Gyroscope people, who hope already to have succeeded in detaching ten B-32 turrets. They asked us if we knew where activities similar to ours are being conducted because they will gladly assist in locating a set of equipment there for training programs.

I can speak as one who has been connected intimately with this kind of hardware. It is truly fascinating, and anyone who looks at it as typical of what might be done to influence future designs of mechanisms will have, I think, many interesting hours of study ahead of him.

The difference between the G.E. and Sperry turrets is that the former will be electrically operated while the latter will be electro-hydraulically operated. I would like to see the schools have both, to keep up the competitive spirit.

CHAIRMAN WILLIAMS: As an educator, I would be very pleased to see some sort of competition among companies along this line.

MR. FAIRCHILD (Tagliabue Co.): Mr. Chairman, there are going to be tens of thousands of small motors available.

PROFESSOR BROWN: All the aircraft turrets use 24-volt d-c. *and* 400-cycle a-c. power sources. The Sperry Company warned that any of these drives will require about a 100-ampere d-c. supply which they expect the institution to provide.

A MEMBER: It seems to me that with Ernie Capelle here, we might get some indication of the magnitude of the industrial instrument field as a war development. You people probably are all familiar with the fact that our petroleum production during the war was about 1,800,000,000 barrels a day, and we got up to about 1,800,000 tons of synthetic rubber a year, and in synthetic gasoline we got up to a rate of about 9,000,000,000 gallons a year. The instrument industry in many people's minds is rather minor and insignificant, but I believe that Ernie Capelle could give us some measure of what the instrument companies have grown to. I think it would be interesting to know what we are really talking about when we discuss the part instruments play.

MR. CAPELLE: In the first place, it was not possible to get satistics on peacetime production as we were set up in Washington, but it was the feeling there, based on whatever information was available, that the industry, speaking now of industrial instruments as defined before, expanded about three times during the war years.

We also tried to get some idea of the potential size of surplus industrial instruments that may become available. We started by assuming that every instrument sold during the years 1942, 1943 and 1944 to government-owned plants was potential surplus. Included were the process plants, such as Chemical Warfare Service, Ordnance facilities, government-owned synthetic-rubber and high-octane plants, and so on. We figured approximately $40,000,000

worth of industrial instruments went into those government-owned plants during those three years.

That is the maximum potential that may become available. I for one do not believe that will occur. Those that went into government-owned high-octane plants will be part of those plants when they are purchased by the gasoline companies operating them. Synthetic rubber plants will be held either as stand-bys or purchased by the gasoline companies holding options on them, and the instruments in them will follow the same course. It is possible, although with the advent of atomic energy, not now probable, that they will keep some of the Chemical Warfare plants making toxic gases as stand-by units.

Where pyrometers are installed on heat-treating furnaces they are, at the moment, being retained as components on those furnaces. In some instances the furnaces and instruments combined are being purchased by various private companies.

So it is logical to suppose that the eventual surplus will not reach $40,000,000 and that the residual amount will be dependent on many decisions yet to be made.

[For report of the joint committee charged with drawing up the Conference resolution on surplus instruments, see page 754.]

PROCEEDINGS (including Discussions) OF THURSDAY AFTERNOON SESSION, OCT. 18.

X-rays—Methods of Measurement

By FITZ-HUGH MARSHALL, Electronics Dep't, Westinghouse Research Laboratories, East Pittsburgh, Pa.

[EDITOR'S NOTE—Dr. Marshall's presentation was not so much a "technical paper" as a demonstration of instruments. He has authorized the following abstract:]

THE traditional tools for detecting and measuring x-rays have been the photographic film, the fluorescent screen and the ionization chamber operating in conjunction with a galvanometer or electrometer. Within the last twenty years the ionization chamber has been modernized by the addition of vacuum-tube amplification, and the Geiger counter and the proportional counter have been introduced as sensitive detectors at extremely low x-ray intensities.

Recently a new tool has been added: a photomultiplier tube measuring the light from a fluorescent screen. The photomultiplier tube combines within one envelope an ordinary photoelectric surface and a nine-stage secondary electron-emission amplifier which increases the output by about a million. This new detector is now being used in automatic x-ray exposure timers for medical and industrial radiography. It will be used in a new non-mechanical superfast x-ray thickness gage. Since this detector is not only extremely sensitive but also has a response time measured in microseconds, it is capable of detecting thickness variations in sheet steel passing through an x-ray beam at speeds greater than can be realized in practice in industrial rolling mills.

Thus, in x-rays as in other fields, new tools continue to appear and to command our attention in scientific education.

Instrumentation in the Mechanical Engineering Curriculum

By CARL F. KAYAN, Associate Professor of Mechanical Engineering, Columbia University, New York

TRAINING of the mechanical engineering student for a career in Instrumentation whether in the rôle ultimately as user or as designer should be substantially the same, certainly for a good part of the way. As a matter of fact, undergraduate training for any mechanical engineer preparing to enter the technical side of engineering should be the same.

Primarily the mechanical engineer will operate in the broad field of process industries—which term I intend to use in its fullest sense as dealing with the preparation or manufacture of a product. Whether this be steam power plant engineering, power by internal combustion equipment, refrigeration, air conditioning, food processing, etc., the engineer has to deal with energy; and therein with its liberation, transformation and utilization; and above all with the control of the processes, either manually through the aid of supervisory instruments, or automatically by engineering devices of control.

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Accordingly, the general problem of Instrumentation is of major fundamental importance. No continuous engineering process can be operated without some form of instrumentation. The subject should therefore be ranked as one of the basic sciences on which mechanical education should be built. For the mechanical engineer it is on a par with thermodynamics, heat transfer, fluid mechanics and electro mechanics, by way of examples. Instruction in Instrumentation should be given therefore to every mechanical engineering undergraduate not as a specialty but rather as a basic requirement.

Of course this leads to the question as to what is to be done for the man seeking a career with a manufacturer, either in design and manufacture, or in the selection, installation and maintenance of equipment. The same answer is here to be given as to the question of what training should be provided for any special field. (We are often asked similar questions by men wishing to make air conditioning or automotive engineering their future career, or even latterly jet propulsion.) I believe that instruction in the special techniques of any engineering field belongs directly to industry—that it is not only its province but also its obligation, and I dare say its preference. The student of course must be previously prepared in the basic fundamentals and general applications of the profession. What now are the basic technical fundamentals of any mechanical engineering curriculum, aside from the non-technical and yet nevertheless extremely necessary general studies that make the engineer?

These divide into two groups: (a) Basic pre-engineering subjects. (b) Basic engineering subjects.

In the initial group are included drafting and descriptive geometry, general chemistry including study of engineering materials, classical physics of mechanics, heat, electricity, light and sound, and now modern nuclear physics, engineering mechanics of statics and dynamics, mathematics including differential and integral calculus and some differential equations. In the next group are, first, subjects of the so-called heat-

and-power group—those dealing with energy analysis as such, and then those of the machine design group. In the heat-and-power group we have thermodynamics and heat transfer, fluid mechanics, electromechanics including electronics, along with general applications such as power generation, refrigeration, and other processes. In the machine design group we have mechanism and kinematics, strength of materials, shop processes, mechanical design and analytical mechanics of machines, including vibrations. Parallel to these groups and certainly at least of equal importance, we have work in Instrumentation.

As is obvious to all of us, Instrumentation encompasses working principles associated with all of the different fields mentioned. In fact, the great fascination in working in Instrumentation is that the study is so broadly general, not only in its foundations but likewise in its applications. In such a sense it represents general engineering.

We must now also in addition recognize for Instrumentation the distinction between steady-state processes and transient processes; furthermore between indicating and recording equipment on one hand, and automatic control equipment on the other hand. For these specific reasons, accordingly, studies in the fields of thermodynamics and fluid dynamics, along with their specific technical applications in heat-power processes, are so important. Much can be learned in the study of allied fields such as heat transfer, with its wide application and inspiration in Instrumentation. This covers steady-state and transient analysis, and the application of general electrical analogies.

How should the subject itself be taught? To my mind, Instrumentation should be taken up only after a student has had a general introductory and qualitative course in mechanical engineering processes, as for example the generation of power from fuels. This then would be followed by thermodynamics, dealing with the quantitative aspects. And since instruments are very much a part of laboratory procedures, the *first* laboratory course should well be one devoted to a study of the general forms, applications, and calibrations of simple instrument test equipment. This then can be the introductory course to the general problem, and at the same time serve a most useful purpose in mechanical laboratory procedure, since later laboratory courses can be devoted entirely to a study of applications. (In this first laboratory course attention will likewise have to be devoted to standard procedures of laboratory technique: herein test codes, etc. will be met for the first time.)

Following this, and now subsequent to the study of engineering sciences such as thermodynamics and the general applications, the student should take a detailed qualitative course critically analyzing the principles of operation and applications of different varieties of instruments. Here first the simple indicating type should be studied, then the recording, and finally the application of the principles to the problem of the automatic controller, with simple systems of automatic control. Included here would also be the application of relay and servo arrangements. At this stage, other than general introduction of the problems of transient operation, the work should be limited to consideration of steady-state conditions.

It is to be noted that of prime importance in such a broad field as Instrumentation is the organization of material and, very definitely so, the classification of the major available instruments. This study, by way of examples, is thus to be carried out on competing methods of pressure instrumentation; and of temperature, by non-electric and electric means as an expeditious method of classification. And in the matter of automatic control, in any one group the industrial regulator should receive attention alongside of the instrument type of controller. Of particular significance, to my mind, is the study of the operating characteristics, as for example, of a pressure-controlling device such as a pressure governor or pressure-reducing valve. Above all, it is to be noted that instruments are to be studied from the functional viewpoint. In such studies, a student should have the opportunity of comparing competitive instruments based on the same principle, as well as competitive instruments of differing principles.

It is obvious, with the tremendous growth of the instrument industry, that a student will never be able to investigate any large number of different instruments, through direct inspection, demonstration, or laboratory work. No text-book could ever hope to cope with such a fast-changing picture. Hence it it is up to the instructor to keep up-to-date and to supplement text-book studies by means of a suitably planned program of using current (and historical) commercial literature. Use of such literature will also permit study of operating data. To my mind, systematic use of commercial catalog material is very important, and considerably augments the literature. Parenthetically it should be noted that it contributes to a student's knowledge of different companies in the field.

Beyond undergraduate work, students pointing to a career in Instrumentation should continue along two broad lines. The first is in advanced work in the usual engineering sciences. The second is in studies on the quantitative aspects of both indication and automatic control equipment, dealing with typical design problems, modern automatic control theory embracing transient analysis, and study of the engineering literature of the different professional organizations such as IIRD of the A.S.M.E., and the recently-formed I.S.A. In this quantitative analysis, of particular significance will be the analytical phases of machine design, advanced mathematics, heat transfer, fluid mechanics, and electronics.

These studies, in turn, should be supplemented by a series of lectures under the guidance of the school or of a professional organization, dealing with specialty design and control problems by individual specialists, preferably from industry. This is adult education!

In conclusion, it should be reiterated, the function of the technical school is to provide the broad fundamental training, but the detailed specialization for the student engineer should be in the hands of the specialist industry.

(The question of curriculum development to permit the inclusion of course work in Instrumentation is a matter of treating the engineering material on the basis of the fundamental subjects of the profession, as outlined above, rather than on the basis of detailed treatment of specialist technologies as hitherto so often done. Instrumentation thus becomes a fundamental subject. For more than twenty years separate laboratory work, and for ten years the detailed treatment of Instrumentation including work on automatic control, have been included in the regular undergraduate curriculum for the mechanical engineer at Columbia University. Herein the material parallels treatment of heat-power subjects, including fluid mechanics, and of machine design subjects.)

DISCUSSION

PROFESSOR DENNISON (Carnegie Tech): May I ask Professor Kayan two questions? Is this course in instrumentation which you are giving part of a four-year undergraduate course? And if so, what did you throw out to put that in?

PROFESSOR KAYAN: The answer to the first is yes, it is part of the four-year curriculum, and it has been in operation about ten years.

About ten years ago we moved out of the mechanical curriculum certain subjects such as steam turbine design and substituted what we considered the more fundamental courses; for instance, for general hydraulics, fluid mechanics; and for the theory of pumps and turbines, fluid acceleration and displacement. We have tried to generalize on the basis of broad fundamentals.

We feel that is a better set-up and makes it possible to treat on the basis of the ruling concept, rather than the basis of specific applications. We were moved in that spirit, particularly referring to the steam turbine design, feeling that, first of all, there were only a few companies in the country designing steam turbines and only a few students possibly would end up in those companies and, second, it was far better to adopt a broader concept of treatment of the problem of the centrifugal machine from the viewpoint of general fluid acceleration. That I should say is our ruling idea; and our curriculum is fashioned on that basis.

Instrumentation for Engineers

By B. J. C. van der HOEVEN, Manager of Operations, Butadiene Div., Koppers Co., Inc., Kobuta, Pa.

LET me start this brief discourse by saying that I know very little about instruments and only slightly more about engineers. I am much indebted to our Instrument Engineer, John Kirkpatrick, for a number of ideas in the following.

Up to about fifteen years ago, while I worked as coke plant operator, we used to know almost all instruments by name and were our own experts in fixing them if they did not work. Sometimes we succeeded in doing this, other times not, partly because we didn't know enough, just as often because the instrument was not very good. Instruments were simple then and we understood nearly all about them. We could readily specify them—or leave them out (especially control instruments) and always we would be sure to provide enough by-passes so that we could go back to hand control and forget about the instrument. Fifteen years ago the engineer was his own instrument man.

Now, things are different. Instruments today are as much like instruments then as a present-day radio is like the 2- or 3-tube sets I used to construct back in 1924. I keep my fingers off my own radio and give it to a radio repair man (who often seems to know as little as I do). Today's engineers are kindly requested by the instrument men to keep their hands off instruments and not try adjustments. Moreover, instruments today if properly applied *do* work and are adjustable within remarkable ranges. In many cases hand control is impossible in modern process work; the process is—at least partly—built around the instruments which are an integral part of the mechanical setup as much as the heat exchangers and distillation columns. The instrument engineer and his staff have become permanent additions to the personnel of the plant or design group. Not to have an instrument engineer and to call in salesmen or service men from the instrument manufacturing concerns is much less satisfactory: They have their own axe to grind.

All of the foregoing is by way of apologizing for the title of this talk. An excellent tool "Modern Instrumentation" has been added to the bag of the engineer. We should ask ourselves: "Is he today equipped to take best advantage of it?"

Elaborating somewhat more on this: Does the project engineer, the design engineer as well as the operating chemical engineer get the most out of the instrument possibilities such as (1) reduction in operating cost by saving in operating labor and material, (2) reduction in capital cost by saving in unnecessary equipment and space.

As to (1): Judicious use of instruments does not mean use of instruments wherever there is space in the pipe-lines and idle curiosity about internal conditions; neither does it mean letting the instrument engineers go wild and install all the latest additions in the catalog just because they sound interesting. If the operating function can just as well be done by a set valve and would not save any labor, don't do it. There is such a thing as overinstrumentation when the resultant saving in operating labor means the addition of an equal number of instrument mechanics. Fascinating physical control apparatus is not always practical. Example, infrared. On the other hand, don't forget that the instrument is always on the job; the operator cannot spend 100% of his time working on one function.

As to (2) especially: Considerable education in Instrumentation of the older as well as young design engineers should be worthwhile. Very sizable savings can be made. Today we can eliminate to a large extent the so-called flywheels in process formerly used to allow the operator breathing space between steps for minor upsets. For example it was good practice formerly to provide reboiler kettles with capacity for say half-hour production between distillation columns operating in series. With a good control mechanism such capacity can now be reduced to perhaps a few minutes. Formerly we installed gas holders preceding compressors; today we often omit them since good control will maintain a constant suction pressure.

It is up to the design and operating engineer to make decisions in the matter of where to or not to install instruments; and he should have adequate knowledge about instrumentation to do so.

All of this has been brought home to me in the last two years during the operation of our butadiene and styrene plant. We started out with a large number of young operating chemical engineers and a large number of instruments essential to operations. The few instrument engineers whom we could get initially had their hands full; in fact the two really good experts we had worked twelve hours each for many weeks. Operations did not get smoothed out until the instruments — all the essential ones—were in tip-top shape and until we had a well-trained crew of some 25 instrument men. At times the operators claimed in their explainable agony that all the instruments were wrong again; the instrument men would claim that the operators talked through their hats and they themselves do not understand the chemical intricacies of the process. I'll never forget one night when I had to keep one of our chief operators and one of our chief instrument men from coming to physical violence. It happened to be Christmas Eve. A lot of this controversy and agony could have been avoided if our average chemical engineer had had more training in instruments. My answer, therefore, to the question "is the engineer properly equipped" is NO!

What sort of training in Instrumentation is mostly needed for engineers? In my opinion what is needed is to add to the present training some basic knowledge about the various classes of instruments and of the theory on which their design is based, thus trying to give them a definite understanding as to the possibilities and limitatons of instrumentation. In other words the same training that is now being given relative to the other tools of unit processes should be given on instruments. To illustrate the need for such knowledge: We had a most awful time with one instrument in butadiene, No. 318, the so-called mole ratio controller for the converter feed. The analysis of the feed would vary over a range of 10 to 20%. The instrument was blamed by the operators. Actually the fault lay on both sides. The instrument at first was not sensitive enough because of inadequate differential across one of the orifices. This was properly adjusted. Secondly, the instrument of course only controls the ratio of two pressure differentials, not the ratio of moles in feed. Hence, variations in composition of one of the flows would upset the feed composition in two ways: directly by its composition, indirectly by change in gravity of the component measured and its effect on the differential. Once the obstreperous still delivering the feed was straightened out, the feed compounds became constant. The point is that the engineer operator was not familiar enough with the function of the controller to give it credit for the job it was doing.

Another limitation in instruments—their accuracy—should become ready knowledge of the engineer. Certain flow instruments like orifice meters are no more accurate than 1 or 2% and calculations in three or more figures should not be depended on if such flowmeters furnish the information. Likewise thermocouples do not split degrees and should not be expected to.

As always, judgment has to temper the conduct of the engineer and operator. It is somewhat foolish to mount, as we did once, certain level indicating devices on control boards and get the operators to depend on them if they

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should go out and look at the actual level in the apparatus themselves anyway. We should not try to make control-board floor-walkers out of chemical operators and make them think that the process actually goes on back of the board. A good chart is not the ultimate aim of operations.

Lastly, I should like to point out that we should not try to make an instrument man out of every engineer that leaves school to the extent that he wants to do his own fixing. That definitely would not improve conditions. We accept the instrument engineer and his helpers at their value, but try to understand what they do and assume that they know their business. Adjusting and repairing instruments, just like adjusting radios, has become enough of a specialized art to leave it to the initiated. We expect the schools to graduate enough engineers, gadget-minded, that will turn to instrument work as a profession. The average engineer need not be so specialized. It might be well to consider giving those engineers that specialize in instruments some more fundamentals of process work than the average mechanical or electrical engineer gets.

Give us, however, chemical and mechanical engineers that are going out as prospective chief engineers or plant managers with enough knowledge about the fundamentals of Instrumentation so that we can use our new tool to best advantage.

DISCUSSION

DR. GORDON (Tennessee Eastman Corp.): I am very glad to see Mr. Van der Hoeven emphasize the matter of costs, because that is a very important point in the field. One gentleman this morning said that we can use the manufacturers' literature and tear out the price lists. I think the price lists should be left in, because after all, the success of our industry depends on costs, and I suppose we have all seen a $500 potentiometer doing a job that an $85 thermometer could do just as well.

MR. WHITE (Atlantic Refining Company): I was intrigued by Mr. Van der Hoeven's statement that you shouldn't put in so many instruments that you have to hire an instrument man for every operator you eliminate. If we are not able to hire some instrument men pretty soon we are going to have to reverse the process and take out the instruments and hire more operators.

MAJOR BEHAR: Mr. Van der Hoeven and other speakers have said that the curricula in which *they* are interested are already overloaded. One discusser this morning even doubted that instrument engineering should be taught in engineering schools! You don't really mean it, gentlemen. In your hearts you all want *more* instrumentation education in all schools.

MR. WILDHACK: I am very glad that the two previous speakers implied that their objectives would be met by the survey course. Already in specialized courses in mechanical and electrical engineering and others there is a good bit of time spent on instruments germane to that field. Yet we all realize there is a lot of instrumentation they will meet after they get out that is not germane to the specialty they follow, or they may not follow the specialty they had expected to. In all of these cases it is expected that the survey course will give each type of engineer or technologist an acquaintance with the types of instruments in other fields, and it is the cheapest and quickest way to get instrumentation in the hands of the people who will use it.

MR. MCMAHON (Republic Flow Meters Co.): It has been very interesting, this discussion on the instrument serviceman, the man using the instruments in process, and the value of his services. I have been on the other side of the fence for the past two years and it is my observation that instrument departments spend about as much time throwing out instruments that the process design department wants to put on, as in putting in instruments. My point is that a good instrument department has a much more difficult time keeping unsuitable instruments from being applied than keeping the proper instruments in the process. Perhaps Mr. Kirkpatrick has some comments on that.

MR. KIRKPATRICK (Kobuta Plant, Koppers Co.): My experience with the salesmen has been to the contrary; and proper instruction will stop that.

MR. WEBB (Carbide & Carbon Chemicals Corp.): I have an observation on this last talk: As an instrument engineer I find that a goodly share of my work is to keep the chemical engineer from putting too many instruments on his unit and, often from misusing those that are on.

CHAIRMAN EXLINE: Mr. Van der Hoeven, do you wish to close in summary?

MR. VAN DER HOEVEN: I don't think there is much more to be said on the discussion, Mr. Chairman, I think most of these people agree with me.

Applied Pilot Plant Instrumentation

By W. C. OFFUTT, Refinery Process Engineer, Gulf Research & Development Co., Pittsburgh, Pa.

THEORETICAL engineering (chemical, mechanical, electrical, or instrument) when broken down to its elements appears to be relatively simple. However, successful applied engineering or instrumentation is difficult and requires years of experience before accurate and mature decisions may be competently made. Assuming the foregoing statements to be true, it is a difficult task to teach applied instrumentation to a college student who is already absorbing his education at capacity. I feel that if certain factors are stressed during instrumentation training, the applied part of instrumentation may be fairly satisfactorily taught to the engineering student.

This discussion briefly mentions some of the important factors relating to the successful training of a student for the applied part of Instrumentation. No attempt will be made to discuss what a theoretical Instrumentation course should include, but only a few of the many factors that are not written in text-books will be mentioned.

Since it is understood that a student of Instrumentation has had the necessary background for the formal study of the subject of automatic control, such subjects as automatic control mechanisms, pyrometry, thermometry, pressure and vacuum gages, recording instruments, etc., should be taught in conjunction with commercially-available instruments. This point is pertinent in order that the student become familiar with the mechanisms and fundamentals, or combinations of these, used in commercially-available instruments. Lack of detailed knowledge of available instruments leads to the design, construction, and calibration of an instrument, by those not competent to do so, for a specific job when such an instrument is already being manufactured which probably would serve the purpose better than the one constructed by an inexperienced engineer. This mistake proves to be an expensive and laborious task and shows signs of incompetency when practiced in pilot plant instrumentation. A lack of general knowledge of the available *types* of commercial instruments also leads to the purchase of all the required instruments from one manufacturer. It is generally known that one instrument company does not lead the field in all phases of instrumentation. This would limit pilot plant instrumentation to the scope of one manufacturer's "line" and, in many cases, would involve the installation of unsatisfactory equipment. This not only is serious from the standpoint of loss of out-of-pocket money, but it is also serious from the standpoint of retarding research.

There should be included in Instrumentation study more than just general theory of instrumentation. An attempt

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Editor's Note—*First* read Mr. Offutt's talk; *then* study his illustrations and read his captions.

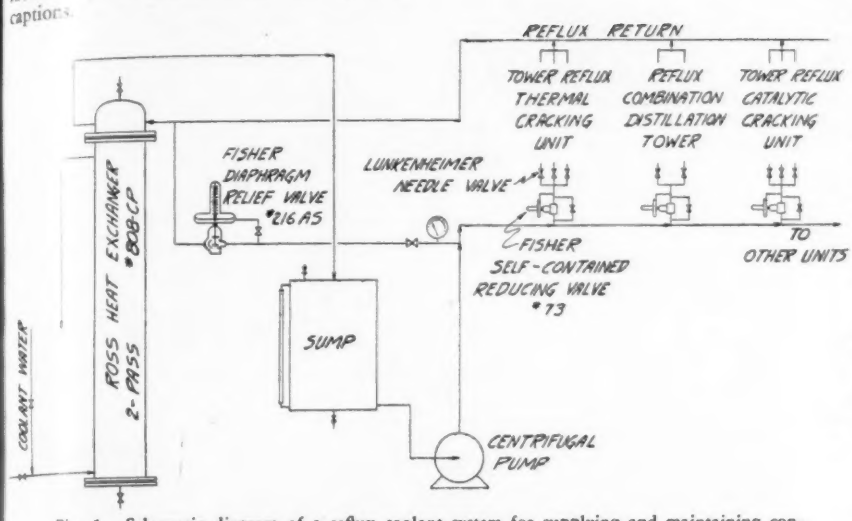
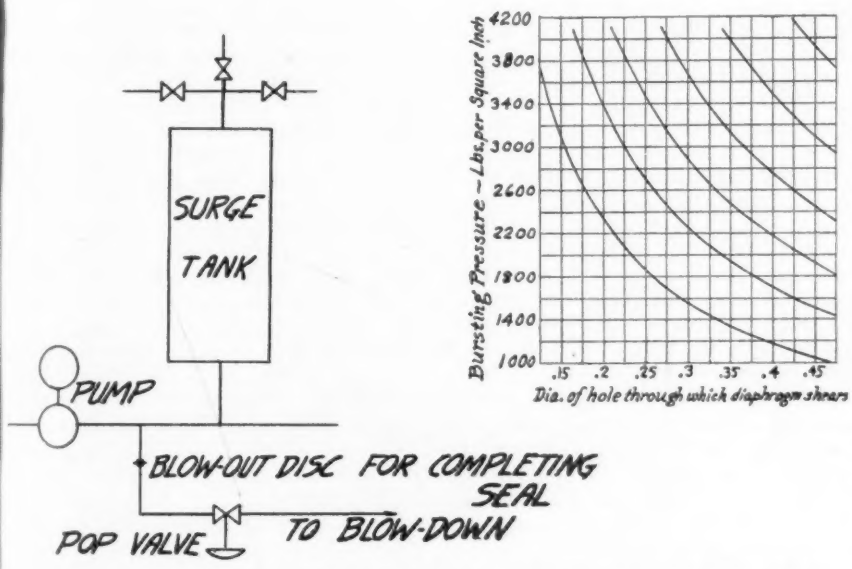


Fig. 1. Schematic diagram of a reflux coolant system for supplying and maintaining constant reflux to pilot plant fractionating systems. The automatic valving maintains constant pressure at each throttling needle valve regardless of the load in the system.



Figs. 2 and 2A illustrate a simple method of obtaining a positive seal on pilot plant flow processes. It is necessary to have safety features incorporated in pilot plants as well as in commercial plants. Most commercial pop valves do not maintain 100% seals, particularly where there are surges in the system. Utilizing a blowout disc before the pop valve completes the seal. Fig. 2A shows the bursting pressures of various diameters and thicknesses of annealed copper diaphragms.

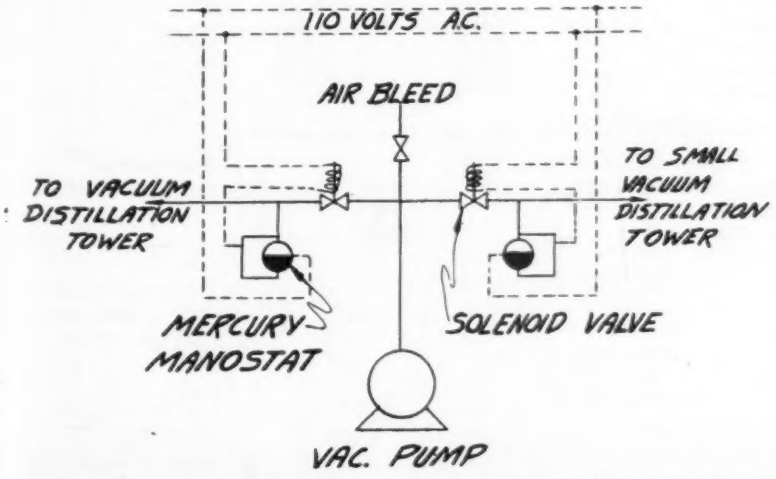


Fig. 3 illustrates a simple method for maintaining of two vacuum levels on separate distillation equipment, utilizing a single vacuum supply.

should be made to give the student a chance to develop resourcefulness in working out his instrument problems. Resourcefulness may be developed by extensive laboratory work with instruments in simulated test set-ups.

In the university engineering course some practical instrumentation work may be included along with unit operations experimental work. The recording of data from the instrument operation and the process itself should be part of the laboratory experiment. The experiments relating to instrumentation should be as thought provoking as possible and should include such practical things as:

1. Experiments relating to the calibration of all types of measuring instruments and automatic control mechanisms.

2. The study of the effects of ambient temperature compensation for gas and liquid-filled thermometers and millivoltmeter type pyrometers.

3. Studies in the effects of height of location of immersed gas and liquid-filled thermometer bulbs and pressure controller taps.

4. Preparation and operation of thermocouples.

5. Experiments relating to the thermoelectric power of various thermocouple systems and stray electromotive forces.

6. Liquid level measurements.

7. Proper immersion of glass thermometers.

Such practical experience obtained from a comprehensive laboratory program in Instrumentation aids in getting a background needed for adjusting instruments on an actual process-control test. This factor is of primary importance as many pilot plant runs have been unsuccessful because of engineers making improper adjustments to instruments.

An inexperienced chemical engineer is unable to discriminate between where precision is required and where precision is not required. One may make the methodical error of making laborious thermocouple calibrations when the absolute temperature would be satisfactory if measured to $\pm 10°$, or neglect to calibrate thermocouples when precision of $\pm 1°$ or less is necessary. A detailed study should be made of the accuracy of standard thermocouple wires produced by reputable instrument companies, calibration of these for most practical purposes being unnecessary. It is well to point out that unless a large number of thermocouples are to be calibrated, it is a much better practice to have the thermocouples calibrated either by the manufacturer or by the National Bureau of Standards than to construct or purchase adequate equipment (and to develop the "know-how") for the calibration of a relatively small number of thermocouples or indicating gages. In addition, accurate calibrations are often not necessary for meas-

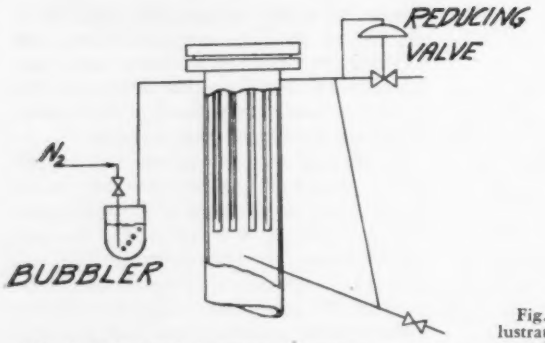


Fig. 4. This sketch illustrates a pressure control on the top of a high-pressure fractionating tower, using a partial condenser for supplying reflux and the condensate product being removed as a liquid. The fractionating tower without nitrogen bubbling through would be practically impossible to control with instrumentation as slight fluctuations in condenser water temperature would cause changes in pressure that could not be controlled by an automatic reducing valve.

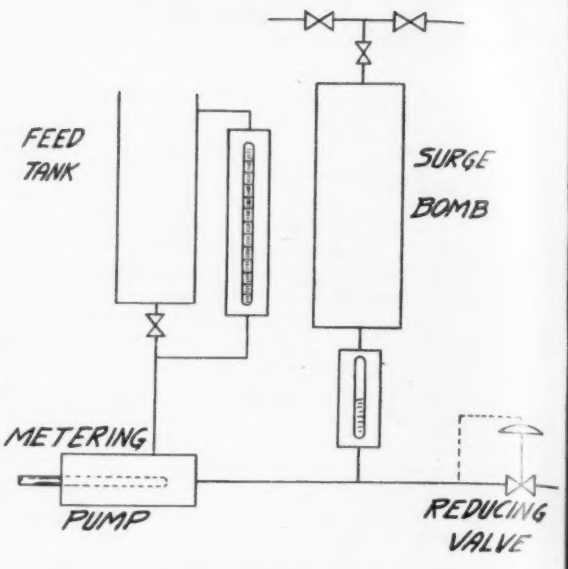


Fig. 5. This diagram illustrates the high-pressure pumping and metering of a low capacity flow. To pump liquids at low rates and high pressures, it is necessary to use a reciprocating type pump. In order to maintain a constant flow, it is necessary to have a large surge bomb and level sight gage before an automatic reducing valve to maintain a constant flow.

uring instruments or automatic-control mechanisms to indicate or record the actual temperatures, pressures, or flow rates precisely, but it is often satisfactory on a relative basis. This is particularly true in pilot plant development work where control instruments are moved from point to point and sensitive indicating gages are used at reference points. It would be a difficult task to calibrate pressure controls every time the point of control is moved from one part of a processing unit to another. It is, therefore, a common practice to use such instruments on a relative basis and rely on an accurate indicating gage for the precision measurement.

It is practically an impossible task to teach and to give a chemical engineering student adequate theory and experience to make him capable of repairing and adjusting all types of instruments. However, it should be possible to supply him with sufficient background to enable him to competently determine whether or not an instrument needs repair or adjustment, or whether or not the system hook-up is faulty. One should realize that an experienced instrument repair man is the most capable person to make repairs and adjustments. Hours of time can be wasted with inexperienced hands working inside an instrument case.

Unless a chemical engineer has had years of experience in instrumentation, it would be impossible for him to become an expert by taking a short instrument course in the university. It should also be pointed out to the student that the instrument course is only supplying a background and that it does not make him capable of being an instrument engineer. In practice, a chemical engineer should be thoroughly familiar with the process problems, and he should rely on the experience of instrument engineers for the final choice of a particular instrument and its accessories to satisfactorily control the process. This should involve a careful selection and a logical choice of auxiliary process equipment, which is expected to be controlled by the instrument. In many cases, particularly in pilot plant work, it is necessary to resort to trick pilot design in order to suit the instrument rather than to develop new instruments to control the pilot plants.

Most instruments are made on uniform production-line basis, but combinations of their auxiliary parts are made to meet the customer's specific problem. Therefore, an automatic-control system cannot be ordered by catalog number only. Temperature ranges, pressure ranges, rates of flow, types of construction materials, and working conditions must be clearly specified on an instrument order.

An instrument system to be ordered for a commercial plant or for a pilot unit must be coördinated with other various departments. For example, before ordering an instrument the chemical engineer must coördinate the requirements of the instrument with the service departments, finding out specifically what services are available, such as voltage and frequencies of the electric power supply, and quantities and pressure of the air supply. Further coordination is desirable with the fabricators who install the thermocouples, pressure taps, etc., in the equipment to be controlled.

It is the opinion of some instrument engineers that a process cannot be controlled by instrument unless it is controllable by hand. This statement is far

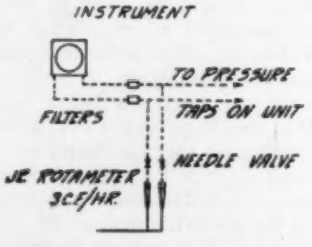
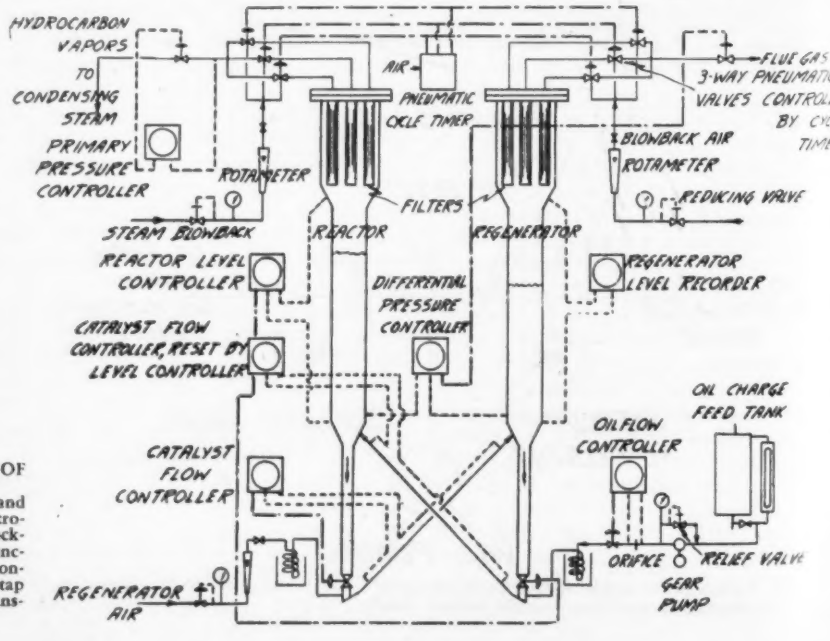
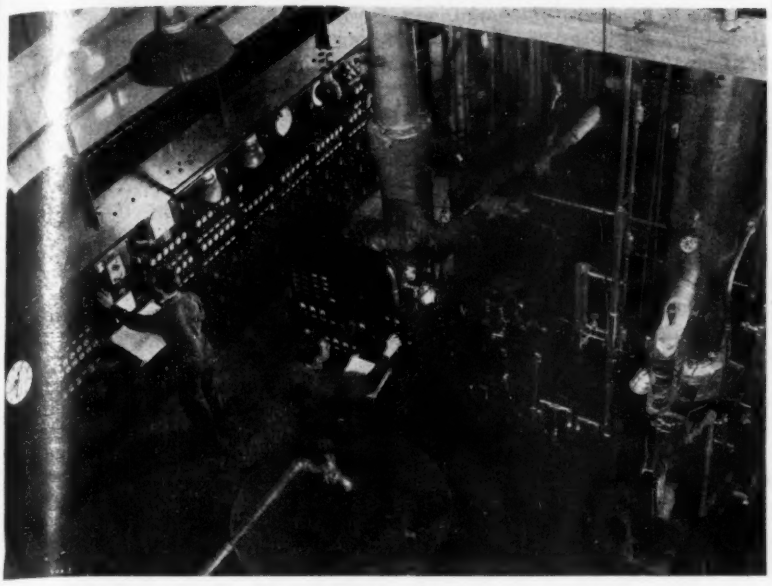


Fig. 6. SIMPLIFIED INSTRUMENT DIAGRAM OF FLUID CATALYTIC CRACKING PILOT UNIT.
This diagram illustrates many types of simple and complicated instrumentation required on a typical petroleum processing pilot unit. It illustrates the interlocking of instruments, the use of cycle timers in conjunction with pneumatic valves, rotameters for visual control, the continuous purging of instrument pressure tap lines, and the utilization of pressure drops across transfer lines and orifices.

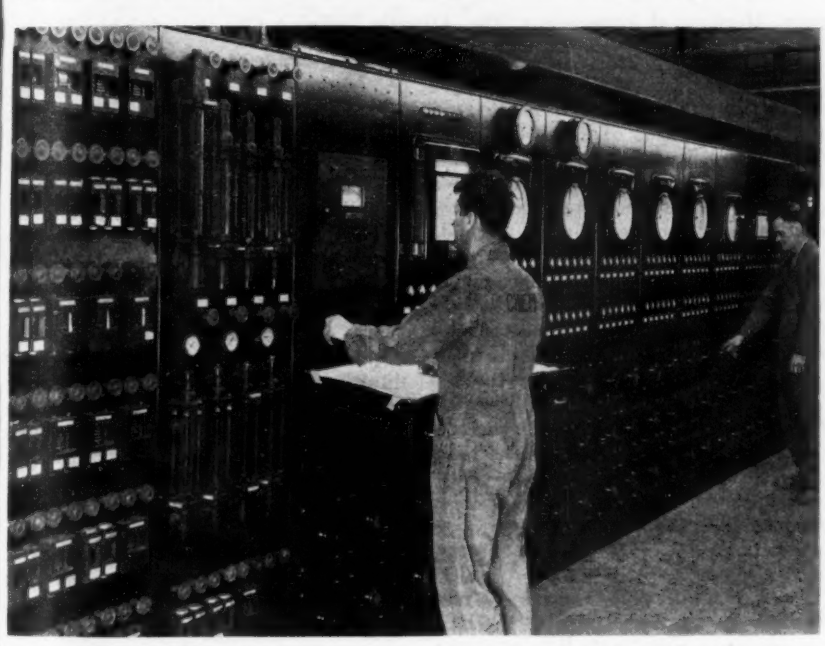




General view of a thermal cracking pilot plant which was used to obtain design data for Gulf's Polyform Process. Several commercial units have been designed and built from this pilot unit. Table I illustrates the accuracy of a properly designed and instrumented pilot unit.

TABLE I—COMPARISON OF LABORATORY AND COMMERCIAL NAPHTHA POLYFORMING

	Commercial Unit	*Laboratory Unit*
Heater Outlet Temperature, °F.....	1030	1030
Naphtha Feed, B/H.....	65.2	65.8 (calc.)
Furnace Charge, B/H.....	128.3	128.5 (calc.)
Absorbed Gas, vol. %.....	96.8	95.2
Yields, vol. % of charge:—		
Gasoline	75.5	75.4
Tar	10.4	9.6
Gas, cu.ft./B chg.....	668	651
Naphtha Charge:—		
°A.P.I.	49.2	50.8
A.S.T.M. Distillation, °F.		
O.P.	175	206
E.P.	460	433
10%	286	300
50%	354	345
90%	426	395
Stabilized Distillate:—		
°A.P.I.	54.6	57.0
Acid Heat, °F.....	111	113
Oxygen Stability, min.....	135	115
R.V.P., lbs./sq.in.	10.3	11.5
A.S.T.M. Distillation, °F.		
O.P.	85	98
E.P.	432	422
10%	130	120
50%	266	267
90%	388	383
S.U.S. at 100°F.....	49.0	44.8
Tar:—		
°A.P.I.	17.9	16.4
S.U.S. at 100°F	49.0	44.8
B. S. & W., wt. %.....	0.1	0.2



This photograph is a view of the control panel for the fluid catalytic cracking pilot unit illustrated in Fig. 6. At the left are two panels of rotameters. The small ones at the extreme left are Fischer & Porter twin Junior rotameters having a maximum capacity between 1 and 3 cu.ft./hr. The other rotameter panel shows the set-up for larger capacities: from 10 gallons of liquid to 150 cu.ft. of gas per hour. Next is a Brown self-balancing potentiometer with three selector switches (one being manipulated) containing 40 thermocouples each. The remainder of the panel board shows the electrical control circuits and the pressure and flow control-pneumatic instruments.

(FRONT COVER.) This is a view of the same panel board, showing also an automatically-controlled constant-temperature condenser and receiver for the collection of catalytically-cracked petroleum products. The small vessel in the right foreground (middle of picture) is a water-oil separator in which the water and oil both are trapped out by gravity through conventional U-type traps.

from true in pilot plant work, and it is also my opinion that it is not true in large-scale commercial process control.

The foregoing statement seems to be the dodge of instrument sales engineers who try to justify the fact that their company's line is not broad enough in scope to cover the entire instrument field, or to justify an opinion based on the lack of knowledge of the possibilities of instrumentation.

Pilot plant instrumentation not only involves the use of instruments but the combination of instruments, pumps, heaters, heat exchangers, etc., designed for specialized control. Many successful instrumentation problems have been worked out in pilot plant operations by using combinations of instruments, with the primary instrument only setting the control point for the second instrument by receiving its signal from that specific part of the process which shows the greatest change first.

Pilot plant instrumentation is as important as the actual experimental data taken from the units in order that a background in instrumentation and control for the commercial process, as well as the pilot plant process, is developed. This involves complete coordination of the pilot plant scale process with the commercial instrument and design engineers. Instrument and control diagrams, photographs of pilot plant instrumentation and component parts, and examples of instrument performance are helpful.

A pilot plant process engineer must acquire sufficient background in order to be fair to the instrument. One must avoid the checking of commercial instruments with inadequate standards. Many cases have been found where the instrument was condemned or thrown out on the basis of using mercurial thermometers which were either inaccurate or were used at the improper immersion.

During the course of pilot plant development, many instrumentation problems arise. Only actual test determines whether or not an instrument is satisfactory, and often it is necessary, as previously mentioned, to resort to trick pilot plant design to suit the instrument. Therefore, the pilot plant development engineer must be broad-minded and not condemn an instrument when it has been misused.

In conclusion, a good chemical or instrument engineer must develop after leaving school because it would be impossible to properly train an instrument engineer to satisfy all specialized fields of industry.

The following slides will illustrate some typical pilot plant instrumentation and control setups.

DISCUSSION

A MEMBER: I have been asking myself during these discussions, what would happen when an electronic device goes wrong? When I go to fiddle with it the tradesman always beats me to the punch. I think some of the work that

we have thought of as engineering work might go to servicemen's or tradesmen's work.

CHAIRMAN EXLINE: We have had many divergent opinions during the Conference; in fact, you might say we have oscillated quite a bit, perhaps we have needed some stability. We have heard some people say that chemical engineers should have intensive courses in Instrumentation so that they would know what to do with any instrument, and others have said that engineers should keep their hands out of the instrument.

A MEMBER: In my opinion, we can profit from the Army on that. The first thing they teach their officers is, You can't give orders unless you know how to take them. So how is a chemical engineer going to supervise the running and maintenance of his equipment if he doesn't know anything about how it works and how to take care of it?

MR. MCMAHON (Republic Flow Meters Co.): I wonder if any thought has been given by either the Instrument Society of America or the colleges of short survey or summer courses? There has been an example of that for a number of years in the Gas Metering Short Course at the University of Oklahoma, given by the petroleum people—the university supplying the facilities and the lectures being given by manufacturers and users of the equipment.

With the intense interest in this subject and the fact that many men in industry would be eager for a survey course, it seems to me that such a course could be sponsored by the Instrument Society of America or, if it does not care at this early time of its life to sponsor such a thing, that the universities might consider such a course. I am sure they would have the collaboration of the manufacturers, who undoubtedly would be glad to follow the practice at the University of Oklahoma where they send the equipment, set it up and demonstrate it and give as complete instruction on it as possible.

That course involves both lectures and classes on theory and practice. Many of the engineers come in, but basically it is for the men who maintain the instruments. However, it seems to me that a similar thing could be put on by some of the universities.

Laboratory Instruction in Instrumentation for University Undergraduates

By MARTIN H. WHITE, General Foreman, Mechanical Laboratory, The Atlantic Refining Co., Philadelphia, Pa.

IN planning a course of instruction in Instrumentation for undergraduate engineers, it must be remembered that instruments are used in so many fields and in so many ways that only a comparatively few phases can be covered in the time which could be allotted it in most already heavily-loaded engineering curricula. There are, however, certain fundamentals which should be of value to almost every engineering student who hopes to enter one of the so-called "process" industries of which the chemical and the oil refining industries are typical examples.

It is my firm belief that this student, when he graduates and takes a position as an engineer in this field, should have more than just a speaking acquaintance with the industrial instruments he will encounter. I do not intend to convey the idea that I favor making skilled instrument mechanics out of our student engineers, but I do feel that they should be familiar enough with the correct application techniques of these instruments to avoid the many pitfalls that await them.

I believe I am safe in saying that there are two subjects about which the majority of engineers know little as they walk across the platform and receive their degrees. One of these is the measurement of flow of fluids through pipe lines and the other is automatic process control. It is the purpose of this paper to emphasize the importance of these two subjects and to offer a method for providing the necessary instruction.

In many cases, laboratory courses in hydraulics give the student a large amount of work on the measurement of the flow of water over weirs and through flow nozzles with open discharges, with little time devoted to the measurement of flow of fluids through pipe lines by means of sharp-edge orifices and flow nozzles. The result of this training is that he probably graduates with the impression that most flow measurements are made by the methods first mentioned and he receives a rude shock when he enters one of the process industries and finds that weirs are almost unheard-of and that flow nozzles with open discharges are seldom used. Instead, he finds that the sharp-edge orifice, because of its ease of installation and maintenance, and its adequately high accuracy, is used in at least nine out of ten installations. Accordingly, he must change his conception of flow measurement completely and start almost from the bottom to learn this new technique.

It is my suggestion that the hydraulics laboratory be equipped with a measuring section, including the necessary lengths of straight pipe and flanges for the installation of orifice plates, with pressure taps located at the conventional distances for flange taps, vena contracta taps and pipe taps. The flow through the section can be supplied by a pump taking suction from a tank and the flow from the measuring section can empty into a second tank or return directly to the first tank. The second tank is, of course, desirable because it can be calibrated and used to check the flow measurements.

Measurement of the pressure differential across the orifice can be made with a simple U-tube manometer, but I strongly recommend the use of one or more of the standard commercial types of flow meters. I say this because I believe it would be of considerable value to the student to have the opportunity to take these meters apart, examine them internally and reassemble them. He should also make an actual calibration of the meter by means of a U-tube manometer.

Each laboratory group should actually install the piping from the orifice taps to the meter. This includes the installation of seal chambers and the necessary equalizing and servicing connections. Instruction along these lines should include the precautions which must be taken under unusual conditions, such as the meter being at a higher elevation than the orifice, or the fluid to be measured having a higher specific gravity than the sealing liquid.

Instruction of this nature may seem to apply more to the maintenance end of the instrumentation field, but I am convinced that any engineer who has anything to do with piping design or instrument application will be able to do a much better job if he has some understanding of the problems involved in installing the equipment and keeping it in operation.

The lectures given in conjunction with this laboratory work should cover the theory of flow measurement with sharp-edge orifices. The development of the fundamental equations is a relatively simple matter, but their application to industrial processes frequently introduces a number of complications. In the first place, the student should be impressed with the fact that he will be called upon frequently to measure the flow of liquids other than water and at temperatures far from atmospheric. This requires him to determine such physical properties of the material as specific gravity and viscosity at the normal temperature and pressure at the orifice.

Similar problems arise when he wants to measure the flow of gases. Having been taught Boyle's Law from the time he first studied physics, he is likely to assume, unless properly informed, that

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Presented at the Conference on Instrumentation And The University, Carnegie Institute of Technology, Pittsburgh, October 16-18, 1945.

this law functions universally. It should be brought out that Boyle's Law is applicable only within narrow limits, particularly in the case of gases of high molecular weight. It is important that he have an understanding of such terms as critical temperature and pressure, pseudo-critical temperature and pressure, reduced temperature and pressure, and fugacity, so that he can work with these properties to determine the specific volume of the gas under actual flowing conditions.

It is not to be expected that the undergraduate student will be able to devote enough time to this phase of his engineering studies to become competent to handle any flow measurement problems that may come his way, but he will be forewarned against the erroneous assumption that they involve nothing but simple arithmetic.

A similar approach must be made in considering the subject of automatic control. Here we have a field which has expanded at an almost unbelievable rate in the last few years, particularly in response to the stimulus of war, until it has reached the point where there is hardly an industry or even a process that does not use it in some way. Again, therefore, I must preface my remarks with the statement that I am speaking from the viewpoint of the process industries and that the instruction I am suggesting applies primarily to pneumatic controllers which predominate in numbers for this type of operation.

The laboratory work should begin with a study of the controller itself. The student should be given the opportunity to examine the mechanical parts and become familiar with the operation and the adjustments of as many makes and types as possible.

Along with this, he should be instructed in the more common type of controller actions, such as: two-position or open-and-shut action, proportional-position or throttling action, floating action, derivative action and reset action. These controller characteristics can be demonstrated in the laboratory by supplying air to the instrument at the specified pressure and putting it through a series of properly selected operations. In this way the student will become familiar with such terms as "differential gap," "proportional band," "floating rate," "reset rate" and "rate time."

It is highly desirable to set up in the laboratory a dummy process for demonstrating the complete automatic control cycle. This can be done without the expenditure of a large amount of money. Such a device is an extremely valuable piece of equipment: with it the student can see the results of applying different types of controllers to a process. He will see at first hand why a two-position or open-and-shut controller will always produce cycling control. He will understand more clearly why a proportional-position or throttling controller will always give an "offset" or "load error" when the process load or demand changes. He will learn how the reset action functions to eliminate this error and he will gain, in a comparatively short time, a comprehension of what automatic controllers can do and under what conditions the different types can be applied.

He will also be able to observe the effect of changing the controller adjustments. He can see for himself, for example: how derivative action affects the initial deviation under rapid load changes; how increasing the width of the proportional band of a proportional-position controller increases the initial deviation and the offset but improves stability in most cases; how increasing the reset rate can produce cycling; and many other automatic-control phenomena. This will not make him an authority on automatic control, but it should provide a foundation upon which he can build through later experience in the profession.

In conclusion, I want to add a word of commendation to all those who had a part in organizing this conference. If we in the industrial field have not been completely satisfied with the instruction which you in the educational field have given student engineers, it is our own fault for not telling you more specifically what was needed.

DISCUSSION

PROFESSOR KAYAN (Columbia University): Mr. White has brought out some very interesting points. Perhaps the point on measurement of flow as brought out in the study of hydraulics could bring us to reconsidering the whole subject of hydraulics as part of the more general subject of fluid mechanics.

MR. HALL (Foxboro Co.): It seems we have a unanimity of opinion, from some of the speakers and the remarks from the audience regarding certain educational requirements. Mr. White, Dr. Miller, Mr. Offutt, Mr. Webb, Mr. Ferguson, Dr. Kayan, Dr. Beitler and Mr. Gordon seem to be pretty open-minded in what is needed. What has been done at Worchester Tech may not be a final thing but it is a start. What we want to do is to get the practical part of instrumentation to as many undergraduates as we can. I am not speaking for my own company, I am speaking for the instrument industry and for the users when I make that statement. I can say that my company offers a very cordial invitation to any educators interested in what we are doing in our own training program and what Worchester Tech is doing, to visit us, and it can be arranged for them to have an opportunity to see what is being done at Worchester Tech. It is a start, and a start is what we need.

MR. WEBB: I wasn't surprised when I was told by an attendant this noon that he had been sitting up in the corner where graduate and undergraduate students sat this morning and that the young men were very much confused by what they had heard. I think you can appreciate how they felt after hearing the discussions these last three days. I am not worried about that confusion, for I have attended many meetings of this general type. I would suggest that anyone who *is* worried wait a month until all this is published, and then be sure to obtain a copy and read those articles in which he is particularly interested. I think he will find more meat and common sense than there seems to be on the face of it. I would suggest that we withhold judgment as to the confusion and lack of progress until we do that very thing.

PROFESSOR BICEK (Illinois Institute of Technology): I would like to make a suggestion concerning one phase of Instrumentation education that I think has been overlooked.

Everyone seems to agree that we should have Instrumentation education all the way from graduate work to short courses for bench men. There have been papers relating to all aspects and there has been general agreement. I would like to suggest, however, that one of the major difficulties is lack of information. A company may expect the student to know the principle and operation of an instrument, but it is almost certain that the company does not have in its own files an adequate technical description of the equipment and its mode of operation and repair.

A professor or instructor trying to teach Instrumentation has to be a superspecialist to keep up with developments in the field. If he attends all the meetings, writes for every bulletin that comes out, and has excellent industrial contacts, he may obtain enough information to be a real up-to-date instructor for his students. If the man in the plant writes for every possible bulletin, talks to all the salesmen and writes long letters of inquiry, he may succeed in garnering the essential facts. The accumulation of the information is a phenomenal secretarial task.

If a man who is teaching didn't have to rely on twenty or thirty years of experience to accumulate the pertinent information, I believe things would move along a lot faster in the teaching of Instrumentation. Some suggestions I would like to make are these:

I would like to see the information put out by the manufacturers in some standard form, not from vest-pocket guides to oversize catalogs.

I would like to see this information available for distribution to the student as primary source and study material. The value to the companies of such information placed in the hands of those who will use or specify such instruments in a few years might well justify the cost of distribution.

I would like to see the use of drawings, exploded views, technical descriptions, charts and data replace the sole dependence on glittering sales promotional generalities.

Finally, I would like to see an

agency, such as the Instrument Society of America for example, act as a central source for all such industrial and technical literature on instruments. If one were able to make his own selection of information from one source rather than the infinitude of sources needed at present, it would be a tremendous and much-needed aid to the dissemination of knowledge concerning modern instruments.

It has always been true that lack of the means for the dissemination of knowledge has held up progress. Such a standardization, improvement and centralization of information on instruments would take us a long way from the present where one may spend many a futile hour tracking down information on one small meter.

MR. SPERRY: The I.S.A. is trying to find out from this Conference the most pressing problem that we, as a new organization, should tackle. We are still an embryo organization but we are soon going to be faced with the problem of establishing certain policies. Frankly, when we plan our publication policy we would like to feel that we were producing literature that is not available to the public today, and something along the lines that has been suggested here may well be a very fertile field for us to consider.

CHAIRMAN EXLINE: I have felt that the problem of securing information of substantial value to the engineer and the student is a real one. We have file cases full of catalogues to which we go when hunting for information on various applications of instruments. I am sure the size of that file could be reduced 50 to 75% if the unnecessary material were weeded out of each catalogue. I don't mean publication of literature without the maker's name on it, but I do feel that there is redundant material, that it is not presented uniformly, that it is difficult at times to get the exact information one needs for a particular application. Some instrument companies have done excellent jobs in presenting such information, but I think much remains to be done and I hope Mr. Wildhack, the chairman of the I.S.A. Committee on Publications, can present concrete recommendations for the solution of this problem.

MR. FAIRCHILD: At the beginning of this conference I was very much encouraged by the tendency to stress the idea of teaching fundamentals in undergraduate courses. Every once in a while, and particularly today, it has been brought up that it is necessary to teach undergraduates factual information about instruments. I wish to call attention to the requirement that has been emphasized by many, that we stick to teaching fundamentals. Dr. Brown and Mr. Campbell of M.I.T. acknowledgedly support this — particularly in automatic control. But, as I was telling Dr. Brown, I think they are steeped in automatic control, and he would think of Instrumentation as largely the study of dynamics.

The point of view as illustrated by Dr. Brown and Mr. Campbell on the one hand and men who think of instrumentation as instrumentation of process industries illustrates that we are all men with narrow points of view trying to talk about very broad subjects.

I would like to point out that there are universally accepted principles of measurement, there are universal principles of automatic control. *These* should be taught to the undergraduate.

So I want to point out that we are always trying to talk from our own little niche, looking through a keyhole at so broad a subject that it is no wonder the students that are here are confused. If we can think of instrumentology as based on the fundamentals of physics and chemistry and mathematics and the allied basic topics of the undergraduate course and build on them, then only can we integrate instrumentology into a coherent whole.

[The Conference adjourned *sine die* at 5:05 p. m., Thursday Oct. 18, 1945]

PROCEEDINGS OF DISCUSSION PERIOD, TUESDAY MORNING SESSION, OCTOBER 16.

(Discussions of papers by Dr. Gerard, Commander Hibbard, Major Callahan, Dr. Powers and Major Bowman.)

CHAIRMAN PIGOTT: Now I throw the discussion open to the floor and will ask each person wishing to ask a question or present a discussion to announce his name and connection; and also to mention the author he wishes to particularly address himself to.

MR. BINKLEMAN (Carnegie Institute): I would like to address a question to Major Callahan, on the "Future Requirements of Instrumentation in Aviation." One of the items you mentioned among the Army's needs for improvement was a lubricant which would work from 200 above to minus 85 degrees. There is a new material called silicone which the Army has used in many phases, rubber gaskets in the supercharger of the B-29 and so on. I believe this material, silicone, has advantages and can resist temperature changes, and though it is not a perfect lubricant it might be improved in a number of years. What has the Army done about that?

MAJOR CALLAHAN: I will say the silicone compounds that have been tried have not shown lubricating qualities to compare with petroleum products; and their lack is serious. However, it is interesting to note other uses of silicone; we have used it at times as an electrical insulating and sealing compound, and for damping fluid for bubble sextants. It would not be proper to say that silicones have lubricating qualities equal to petroleum, although we are very much interested in information on the subject.

CHAIRMAN PIGOTT: The Chair can offer something else in answer to that question. Not only the silicones but a number of other products which we hadn't considered heretofore as possible lubricants are being investigated, among them a group of diesters. It is interesting to know that the Elgin watch oil used during this war has no hydrocarbon petroleum lubricants. It is entirely synthetic: there are I believe five different synthetics in it. The only reason I know about this particular lubricant is that it was developed at the Gulf Laboratories.

There will be a wide range of lubricants which are not hydrocarbon products. The main difficulty with hydrocarbons is that God didn't make them with a flat viscosity index; they were not made to be used from minus 85 to 200. There are some good lubricants, including greases, which have been developed to the point where you eliminate sweating. As you all know, a grease is made of oil mixed with a metallic soap, as a rule, and there are ranges of temperature which cause the oil to sweep out of the soap, spoiling the grease in operation. Some of those in which that defect has been stopped consist of some of these new synthetic compounds.

MAJOR BEHAR (Pittsburgh Section, I.S.A.): Since we are starting on the good Major from Wright Field, here is another for him. He told us that one of the future requirements is automatic indication of balance of loaded aircraft. A few months ago an instrument company, I think in California, announced that they had developed instruments which they claimed would integrate all the weight factors—that is, all the longitudinal moments; not the lateral—and compute the balance location to a fraction of one percent of the mean aerodynamic chord. One of these instruments does require some computation by a human operator, but a minimum according to the announcement: mostly drawing straight lines on special graphs—the kind of work the navigator does so quickly. The other instrument, however, was said to be fully automatic and although I didn't see a technical description—only a picture—it seems to be an electrical calculating machine into which you feed the fixed weight factors such as passengers and cargo, and their distances. In addition I think there was something about fuel consumption compensation: as fuel weight is reduced in flight, that reduction — as distributed among the different fuel tanks—is also taken into account.

MAJOR CALLAHAN: I believe I can answer that question, although I

am n familiar with the California projec The work recently has been direct along two lines. On the groun of course we support on three points the two main landing gears and the ta wheel or nose wheel, and by static strain gages at those three points, if there is no wind, we can distribut the total weight reflected by those three points. However, in flight, the work that has been done is in using structural members, top or bottom, and measuring the strain in these member s, thereby giving an indication of lon itudinal distribution of weight.

But of course on the ground the problem is complicated by wind, and we have to establish these values with or without the wind and, frankly, the tests to date with which I am familiar have not shown sufficient sensitivity. We have to know the center of gravity position to within one one-hundredth of one percent of the chord of an aircraft, the chord being the distance between the leading edge and the trailing edge, the total area divided by the span, and that is of the order of six feet in a fighter and thirteen feet in a B-17 class aircraft. We have to know that within one one-hundredth of one percent, and we haven't yet been able to repeat the readings with the same gages to that accuracy. It has been nearer to the order of one percent.

MR. FAIRCHILD (C. J. Tagliabue Co.): I guess I will pick on Major Callahan again. Stating a problem in instrumentation doesn't necessarily mean that an instrument ought to be designed to solve the problem. A simple illustration is a lubricant that will work from minus 80 to 200 degrees. Of course lubricant engineers and scientists probably can develop a lubricant that will be excellent over that range, but at the same time another group can develop a better lubricant for a narrower range, and it brings up the possibility that perhaps we should control the temperature of the instrument rather than provide for that range of temperature. The point is that once we have stated a problem it does not always follow that instruments should be designed to provide the answer.

MAJOR CALLAHAN: Our wars are increasing in tempo; they may start very quickly and be over very quickly. We are contemplating air-borne armies. It is permissible to say now that at the beginning of the war, planes which were ordered to England got as far as Newfoundland when they were ordered on December 7 to return to the Pacific Coast to forestall the possibility of Japanese invasion, and later they were again on their way to Newfoundland, Iceland and England.

We cannot wait for winterization, we cannot have equipment, as we have today in a good many applications, which has to be particularly lubricated, particularly heated or changed (tires, hydraulic systems, lubricants, hoses) for Arctic operations and then have the aircraft ordered down to the Panama

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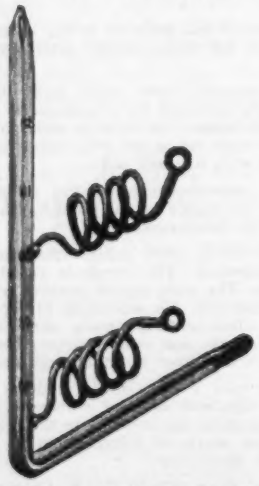

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The general idea back of some of those problems I gave you was to accomplish the quick transportation of our armies to any part of the world, from Alaska to Panama, depending on the requirements and the circumstances.

PROFESSOR WILLIAMS (Carnegie Tech): I should like to address this question to Dr. Powers. What are the prospects, under the present point system, of getting back very many of our students of scientific subjects, and what steps could we take as individuals or as a scientific society to accelerate the return of those men?

DR. POWERS: That is a hard one. The chief difficulty derives from the fact that our younger scientists were deferred at first, so they were the last ones to go into the military services when they cancelled deferments late in the war. They will, therefore, be the last ones to get out. That means it will be a year or two from now before they come out in large numbers. In the meantime, they are still going in.

Now what we can do about that is the hardest part of the question. There is a bill before Congress right now proposing to authorize the release of scientists from active military service and the deferment of those not already drafted. One answer is to support that bill. The indications which I am able to pick up in Washington are that it is not very promising. Therefore, the only recommendation I can make is to approach the problem in other ways as well as to support that bill in whatever way possible.

MR. FERGUSON (Chicago Section, I.S.A.): I should like to address a comment to Commander Hibbard, on his paper, "Human Engineering and Instruments," which I hope will be of interest to this Conference. I am employed by a gas company. Three years ago our company decided that it would be desirable to change the dials on our gas meters. Most of you are familiar with the old type dial consisting of five or six little rings with pointers. Even though it costs us about two and a half times as much to put in the type of dial which reads like a speedometer, it has saved time in reading, and the saving in manpower, the smaller number of mistakes and the enhanced customer good-will, more than paid for it in a couple of years.

This is an example of the point that Commander Hibbard brought out about instruments having to be of such a design that the messages they want to give can be readily assimilated by whoever is using them.

COMMANDER HIBBARD: That is extremely interesting. I was sorry that I couldn't bring in examples of power and heating problems in industry and in homes. I have often noticed the instrumentation in apartment houses; the architects put them in, but the architects are not instrument engineers. It is a simple case—and a very prevalent one — of instrumentation that could stand a great amount of human engineering. Your comment was very much to the point.

CHAIRMAN PIGOTT: A further confirmation of the eye desiring a pattern rather than to read the number from a dial is shown in just exactly what the gas companies do. If the meterman can't get into your house to read the meter he sends you a card and asks you to indicate the position of the dials on the card; he doesn't even figure you are intelligent enough to read the numbers. And the strange thing is that he is right: the average person cannot read a gas meter, he will miss particularly if, say, a pointer is half-way between 8 and 9. If a man sees the position of a pointer on a dial, that is one thing, but reading a number from the position is difficult to do in a hurry.

MR. FERGUSON: And you have seen some of these electric clocks which instead of hands have a dial reading "1:33," and even if the numbers are smaller and in the background, I think they are more legible.

CHAIRMAN PIGOTT: One thing I would like to draw to the attention of everybody, especially those dealing with things on the human side, such as Dr. Gerard's and Dr. Power's papers, is that we are going to have to be very careful in giving technical training to a man, whether a scientist or a physicist or that lower grade of man, an engineer, to inculcate that faculty of reception. You sometime have to go from old instruments to new, and unless you inculcate the faculty of imagination our inventions won't be made fast enough.

MR. SPERRY (President, I. S. A.): When Commander Hibbard and Major Callahan were talking, one question

ran through my mind in view of the newspapers reports about secrecy: How are we going to develop atomic power and keep ahead? I don't refer to the Armed Services specifically and I realize that it was necessary during the war, but there seems to be a tendency to continue restricting research and this may prevent us from achieving the results that these three gentlemen feel we ought to develop.

CHAIRMAN PIGOTT: Does anyone have an answer to that?

MAJOR CALLAHAN: There is this week a fair out at Wright Field to which you are all invited, which has taken the course of action desired by Mr. Sperry, inasmuch as you find jet engined planes performing on the field and the latest of aircraft (the P-83 that was delivered by Republic Aviation on the opening day) is there for your inspection.

I think the general policy of the Army Air Forces now will be much as it was before the war, which was very free. They were very careful before they classified anything as secret. I think it began last week with this fair that is now going on at Wright Field. While there is no advertising, it is an attempt to present the actual developments by the Army Air Forces, accomplished by you, universities and by industry, and it is quite up to date. I can assure you that you will be astounded at the type of items that have been publicized.

CHAIRMAN PIGOTT: Of course, during the war the necessity for secrecy was obvious, but I think we should all remind ourselves of one thing: There is no such thing as permanent secrecy in any subject. The only advantage you get from secrecy is a moderate length of time; and as a rule that is the only advantage. But it can be overdone, and I can illustrate. During the last war Bridgeport Brass, for which I worked, was the first to convert from the old pit method. I was aiding in the melting of a million and a half pounds of brass, which was very fine, but I made the mistake of taking a group through there, and when I was called on it I said, "That is all right, all you have to do is hire a workman and you will know it," which was done, "but you can't get our experience on it." You can't hold the secret for more than six months to a year. We know that on the atomic bomb. You can't keep that information secret forever.

DR. POWERS: Another comment I might make on that factor of secrecy is that there are five bills before Congress right now whose general purpose is to promote scientific research and development in every way possible. It seems pretty clear from the hearings thus far, within the last week, that some such bill is going to be passed, whether it is the May bill, the Fulbright bill, the Kilgore bill, the Magnuson bill or the Byrd bill. The discussion has gotten to the point of not, "Shall

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we have such a bill?" but, "What shall be in it?"

And in at least three of the bills, there is provision for the dissemination of information to do the jobs for which the bills are primarily designed, that is, scientific research in as big a way as possible throughout the country, with the allocation of funds for that purpose. I don't know whether these provisions are going to be passed, but it looks hopeful, I think.

MR. SPERRY: I have read about those bills; and there is one other discussion I have noticed in the newspapers. In the extreme case one bill mentioned a penalty for a scientist discussing some of the things if they were still classified. I saw even a fantastic figure of a $100,000 or $200,000 fine. I think they flatter the scientists!

Also in regard to your comment, Major Callahan, I do know that the Army and Navy Air Forces are exposing much of the work that has been done during the war, but there is still this thought, even in these bills, of providing some sort of a super-super committee that can make it a jail offense for somebody to talk about research. Frankly, I don't think that is even physically possible.

COMMANDER HIBBARD: I would like to make a short answer to that. The problem from within the military circles is a very difficult one, and sometimes from outside it seems very stuffy. On the other hand, I think it is only in public discussions that you find that to be the case. If somebody comes in with an idea on instruments, for instance, say as a result of suggested problems such as Major Callahan has listed today, you will find that the Army or Navy will open up completely to those technical men and give them all the benefits of all the work that has been done along that line. The secrets are more or less secret from the public but not from the technical men involved, once they get working on a problem.

One of the most naive problems that came up, I think, so far as the Navy was concerned, was how to build little model ships of the Navy so that people could learn to recognize them. That was one of our problems at the very start of the war. We could get the plans of most of the ships of all the navies except the U. S. Navy and, frankly, we never did solve that problem in the Navy until one of the manufacturers came down and said, "I won't need any plans, if you will let me stand on Brooklyn Bridge." That solved the problem.

MR. YOUNG (Westinghouse): I want to make a couple of observations, although the discussion got ahead of me. On the subject under discussion, I could write a book about the difficulties of getting into and out of the Navy Building with a brief-case, but I have never found any difficulty in getting information on anything after I got in there, and that applies to the Army, too: it is surprising how they open up to you. That has been my personal experience.

I wanted to mention that I didn't think Major Callahan's requests or the things that he predicted for the future were at all too ambitious, and I particularly wanted to mention to Commander Hibbard that, please God, propagandize this talk of yours to the Armed Services, about simplicity, particularly against trying to put four or five pointers on one instrument. My business is instruments, and I have been having an awful time trying to not allow five pointers to get on them.

PROFESSOR BROWN (M.I.T.): I would like to add my two cents' worth on these remarks about security, because I have been troubled by it during the war. I admit that you can go to Army and Navy buildings and be told a lot, but then there never is any clear statement of what you may do with that information once you receive it. I think we should clarify in our minds the distinction between Wright Field letting the public come in and see that we have jet-propelled airplanes and all kinds of automatically-operated turrets; and the other problem, which is that of letting the scientist or the engineer examine these things and work up a rigorous technical story that is coherent, use the information in his professional work and appear freely before his professional societies to give a talk on the basic principles.

I am not for a moment interested in an announcement that radar worked on HE-X, on lower M, or anything else — the enemy probably knew that within five minutes of the first gadget being used — but the technical brains of this country still have a great deal to learn about these things and it requires clarification on the extent to which technical knowledge is disseminated, as opposed to the mere statement of fact that radar was used. That, I think, is the greater problem concerning security.

CHAIRMAN PIGOTT: I would myself like to come to the assistance of the Army and Navy, if they need it, by saying that certainly we had a lot of restrictions, perhaps at times ridiculous restrictions, but remember that was at a time when you were going into a big organization with a lot of younger and perhaps irresponsible younger men and you had to be careful. Remember also that it was perhaps as difficult to get into Wright Aeronautical as to get into Wright Field. We know this, that in the larger organizations the Army and Navy put everything on the table. In those cases they were allowed special liberties by higher officers, because the people along the table were high enough and you knew they had enough judgment to properly use that information. Remember that you had green men and it was a question of how much liberty you could give them. When you got to the right people it wasn't so bad.

PROFESSOR POLLARD (University of Tennessee): I would like to make a few more comments on this security problem, not so much with respect to the matter of security as it has been functioning during the war, but with respect to the problem of normal university research in the future which is not specifically directed to military ends. Take for example the field of nuclear physics. I think there is a very real danger that we sterilize future research in such a field through security restrictions. The individual investigator will never know to what extent he is violating such restrictions by using knowledge which he perhaps gained during the war while doing secret work when he continues with research not directly connected with that former work but in the general field. It is simply not feasible to apply secrecy restrictions to fundamental research.

PROCEEDINGS OF DISCUSSION PERIOD, TUESDAY AFTERNOON SESSION, OCT. 16.

(Discussions of papers by Dr. Allen, Dr. Worthing, Dr. Pollard, Mr. Webb and Mr. Ferguson.

CHAIRMAN MCCABE: We will now open discussion of the five papers presented this afternoon. I suggest that we take first the papers by Drs. Allen and Worthing, since those papers fall into one group, whereas the last three papers deal with various phases of the educational program.

I call for discussion now on either Dr. Allen's paper or Dr. Worthing's paper.

MR. FAIRCHILD: I notice that Dr. Allen didn't say anything about automatic control, although this is an instrumentation conference. It would seem that the physicists working on the atomic bomb work didn't know about automatic control as we know it.

It is very evident from the literature that the physicists had the problem of how they were going to work with the material without losing their lives, so we hear about the chain reaction and prevention of temperature rise to prevent explosion, and I noticed that the published papers didn't bring out the interesting aspects to the instrument engineer. Then Dr. Allen spoke of maintaining the chain reaction when the average number of neutrons generated per neutron was greater than unity. It is very apparent with a moment's thought that if all the neutrons generated above unity were fast, there

would be an instantaneous explosion that could not be controlled. The speaker did not bring out the fact that the reason they could use the pile in which the chain reaction was possible without explosion was due to the fact that a good many of the neutrons were slow neutrons and were not given off instantaneously but after a second or perhaps quite a few seconds.

CHAIRMAN MCCABE: Those points can't be answered just now, but Dr. Worthing is here. Are there any points of discussion or questions to be directed to Dr. Worthing? . . . I might discuss his paper myself. His talk certainly struck a responsive chord. In my work in outlining these concepts to young engineers, I long have been sick of hearing students trying to tell me that temperature and heat both were the kinetic energy of molecules, for, as a matter of fact, when we measure temperature or heat we usually do so without worrying about whether there are molecules or not. I am thoroughly convinced that in basing the two concepts on the first and second laws of thermodynamics as Dr. Worthing has done, we have the only method of really teaching technical students that I have struck so far.

Let's turn now to the last three papers, by Dr. Pollard and Messrs. Webb and Ferguson.

PROFESSOR SCHOENBERN (University of Delaware): I would like to comment briefly on the talks of Mr. Webb and Mr. Ferguson. I believe the general ideas as given are very commendable. However, in view of the already overloaded curricula in engineering schools and the general trend to include more and more of the humanities in our program, I am wondering how it is going to be possible to include more and more special courses in the undergraduate program.

Wouldn't it be better to have some elective courses, or even a fifth year for those men interested in instrumentation? Or, even better, have an extension course which students in the university can attend and also open to men in industry. For the last five or six years in Wilmington we have been giving extension courses to men in the area, and also in the Philadelphia area, and they have been quite successful. I am sure such courses will go over.

CHAIRMAN MCCABE: Mr. Webb, have you any comment on that question?

MR. WEBB: I have more or less foreseen this same thing, as I stated in the forepart of my talk that I didn't understand how you could put these courses in your present curricula. But I would like to say now that it wasn't my idea that such a course as I was suggesting was for the purpose of training the man for instrument work with a large corporation. What I have in the background is this: I have had quite a few

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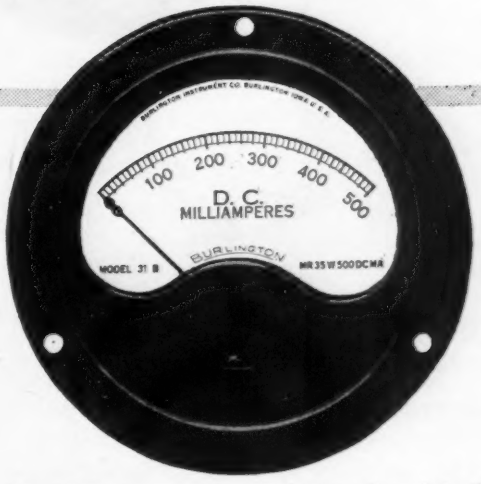

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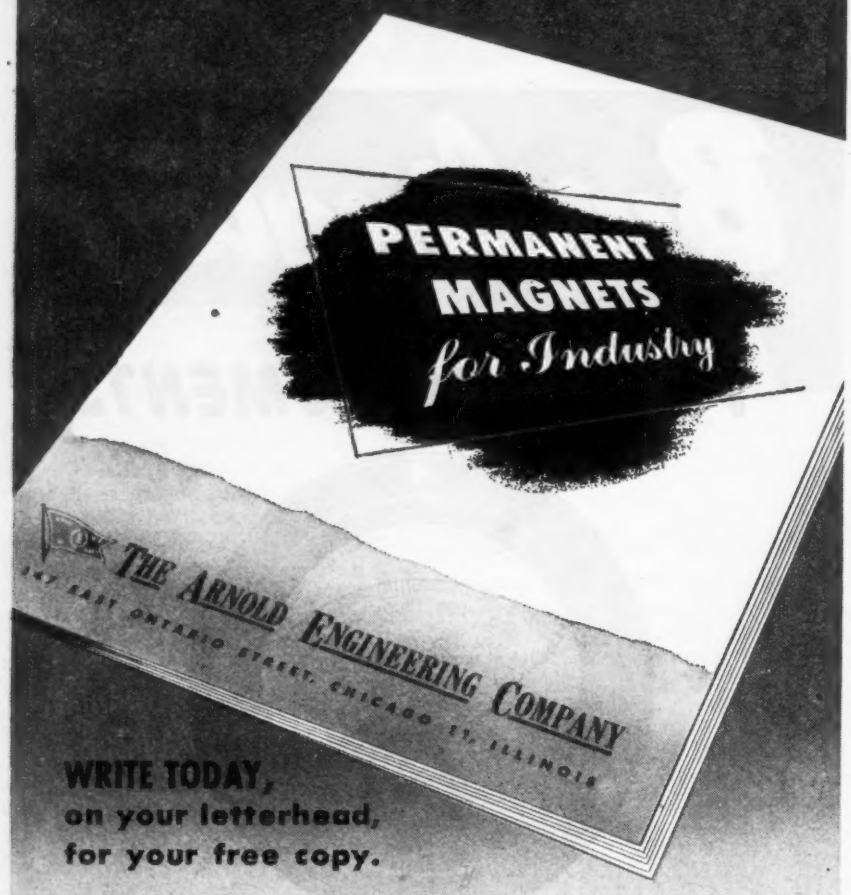

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about instrumentation. They don't know how to put on a pressure gage. Three young men I have had brought in, graduate chemical engineers, couldn't understand at first the simple little $1.50 regulator used in the instrument and couldn't understand the parts in it or understand their working. Those things are disconcerting.

That is what I want to stress: Train these boys so when they walk into a plant they can use these instruments that are so important to their work, in all fields, chemical engineering, mechanical engineering and so on.

MR. PELLETTERE (Gulf Oil Co.): In the after-school work of a so-called chemical engineer, he is called upon to design and lay out plants; and in the final analysis his plant works only as good as the instruments that go with the plant, and his education must not stop at that point where he has not learned that there is instrumentation. It is not often that a graduate after leaving school falls into an organization where he has help in instrumentation; and it is all too often that the plant is laid out along chemical engineering lines and then is turned over to a draftsman for instrumentation. You wouldn't build your home and turn the plumbing over to the garbage department.

CHAIRMAN MCCABE: We are approaching the central theme of this Conference, recognizing on our part that there is a job to be done, recognizing also the crowded schedules of teachers and others, which we will take up in the next two days. But this brings out exactly what we must have in mind in this Conference, and perhaps we will arrive at some tentative conclusions on how the job can be done.

We are glad to hear these discussions, we hope there will be more in the next two days. Don't pull your punches. We want to get all the suggestions that this group can give us.

MR. CAMPBELL (M.I.T.): [To Mr. Pellettere of Gulf Oil] If you had a man of these capacities you have just talked about, would you pay him $10,000 a year?

MR. BOLCERZAK (Pittsburgh Coke & Chemical Co.): I would like to give support to Mr. Ferguson's suggestion for increasing the ability of men in industry to use instruments and maintain them. I don't think I am peculiar in my position. I maintain instruments at the Pittsburgh Coke & Chemical and I feel the lack of instruction on new electronic developments, something simple that will help me in a logical way to test electronic equipment. I would also like some refresher courses on, say, flow measurement calculations—calculation of orifices and of similar flowmeter devices.

I wonder if the best way wouldn't be to have these courses at the week-end when plants are down to a five-day week; or you might have summer school courses where a man may attend school as part of his vacation, at

least the evenings of his vacation.

CHAIRMAN MCCABE: I believe those comments fall in with Mr. Ferguson's talk. Mr. Ferguson, would you comment on these suggestions?

MR. FERGUSON: I am glad several other gentlemen say the same thing as we do. I don't think we should look down on a man because he is a maintenance man. He is a necessity; every industry must have him. The better the maintenance this man can provide, the better for the industry. If the universities don't feel they can stoop to such a low level as to help them out, somebody else will. But nevertheless, we want to have the educational ability of the universities in helping us instruct these men.

DR. MOUZON (Brown Instrument Co.): There are a couple of comments I would like to make. First in conjunction with Dr. Pollard's talk relative to obtaining instruments which are surplus for colleges. One thought that might be worth looking into is that there are many university men at the present time in government laboratories. It conceivably might be possible to work out some set-up where these men could be of great value in connection with seeing that the universities get the kind of instruments they want, in seeing that the instruments are as they should be. I personally know of a great deal of equipment which the Navy has which could very easily be surveyed most any time and nobody would know the difference, but it is very likely to be sitting right there by the time the next war comes along, just as a warehouse full of tires was sitting in the Navy Yard when this war started.

But it may be possible to work out something with the university men who are in government laboratories, perhaps no authority could be given to those people to release instruments but maybe they might be of value in that connection. They certainly know what is available and they know what the universities want.

The other comment I would like to make is in conjunction with the talk of Mr. Ferguson. The instrument companies, a number of them, have already made a start toward the solution of the problem of the short courses which he mentioned. Instrument companies, several of them, welcome representatives from various industrial organizations to come in to the schools which they are running at the present time and learn installation, operation, maintenance and a certain amount of theory relative to those instruments. It might be possible by sending one representative from one company to let him come back and teach the fellows who require that knowledge. I personally think the university is not the place to teach maintenance.

CHAIRMAN MCCABE: Dr. Pollard, have you any comments?

DR. POLLARD: That was an excellent suggestion of one way the universities

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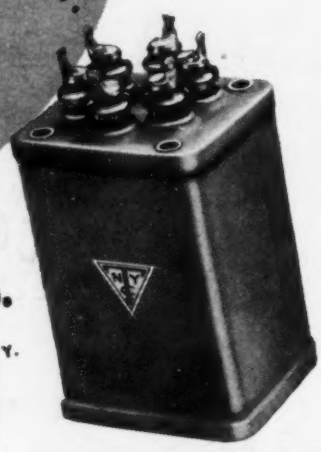

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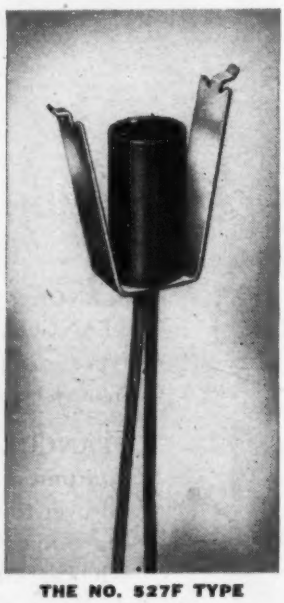

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might find out what is available as their men who are on leave go back to them. However, I am afraid that most of the instruments in government laboratories will not go into surplus property. At least I know of none which are likely to do so. Probably those that will appear in surplus property are those of emergency war plants that are now being dismantled or will be dismantled and it is difficult to get any information about them.

DR. MOUZON: It is my information—correct me if I am wrong—that government laboratories are receiving rather complete lists of surplus material that is available, and it is also my understanding that if they want one of something they get 25 or a carload.

A MEMBER: I belong to a rather large Naval research organization myself, and I don't know how to get these instruments these gentlemen are talking about. You have these lists and you call for them and you don't seem to be able to get them. I heard that the big research organization at M. I. T. is being disbanded soon and we were going to get our fingers in on the kill and get the instruments, but we haven't been able to do so. If these gentlemen know how to get them they know more than I do.

Now as to undergraduate courses. What are these courses for? How many people are we going to try to please in these undergraduate courses? In my class we had casualties I think of some 90%, and if we have these fine instrument courses we will have casualties of 99%. I have seen men that wanted the fundamentals that they needed, men with wives and children who wanted to learn what they have to know. I believe the undergraduate's work should be devoted to fundamentals and if a mathematician wants to write a mathematical paper we will try to go along with him. But let us have men who can write these textbooks for undergraduate work in such a way that mathematics is woven in as examples of problems and not take the time on problems as problems, as in the cultural courses. I say if you are going to give the undergraduate anything outside of what he has to have in fundamentals, give him culture.

CHAIRMAN MCCABE: I think there is one point on the surplus property problem, one difficulty that has not been mentioned; namely, that the contractor has first whack. When we ask for surplus property we get an answer something like this: "Well, yes, there is a fair chance of your getting process equipment and a fair chance in getting some shop equipment, and in fact, there is a fair chance of your getting almost anything, provided it isn't instruments." I would suggest to those that do come in contact with these surpluses: keep your eyes open for items that seem to be in sound condition, then get in touch with the nearest technical school and tip them off.

MR. SAUNDERS (Wheelco Instrument

(Co.): It may interest this conference to know that there is a committee working under the Scientific Apparatus Manufacturers' Association, composed mostly of the instrument manufacturers, who in turn are working closely with the disposal agencies in Washington and elsewhere, trying to set up a policy for the disposal of instruments and establish the mechanics, after proper classification and coding of the instruments in order that you may get the right kind of identification when you look over the list, to make it possible to have them place drafts in the hands of the schools and universities.

PROFESSOR BICEK (Illinois Inst. of Tech.): I would like to second the statements on fundamental education rather than specialized instrumentation courses, and address a question to Mr. Ferguson. As a member of a Chemical faculty I think in terms of potentiometers and spectroscopes and similar instruments. It seems that the trend of the discussion has been the measurement of pressures, temperatures and flows. Since I am trying to find out what courses are desired, I would like to ask whether the courses desired really do relate to such routine engineering applications only. If that is the color of the Conference, am I wrong in thinking that instrumentation applies also to electronic equipment, spectrographs, refractometers and things like that?

I can understand Mr. Ferguson's reference to specialized courses in industry, but it seems hopeless to talk about instrumentation in college as a single course covering mechanical, electrical or chemical engineering, physics and chemistry. I wonder if such a course wouldn't be a hopeless thing unless considered for a specific department and based largely on fundamentals.

I want to know whether Mr. Ferguson was really thinking in terms of temperature, pressure and flow, or whether all instruments are being considered.

MR. HANSON (Du Pont): I think that I can answer that question in part by an illustration. About six years ago, I attempted to hire a graduate chemist who had taken college physics with electives in electronics and engineering to develop special instruments. I found that the simple question, "What is the difference between a voltmeter and an ammeter?" was enough to eliminate ninety percent of the candidates. I also found that students who majored in physics or engineering had the best background for instrument development work.

While the emphasis of the papers appears to favor the few who might become instrument engineers, there are other ways in which the same benefits could be realized for larger groups without the addition of such courses. If more instruments were available in college laboratories and students were encouraged to use them in their experiments, a greater number of students

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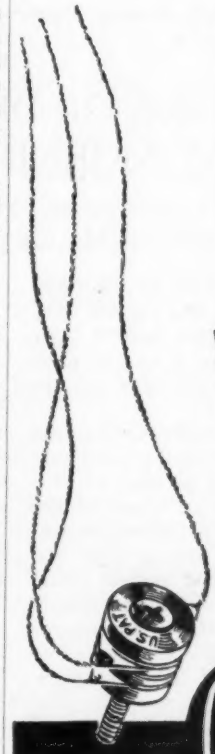

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would develop an understanding of how they work and what they can do.

This will not only be of value to the few who will become instrument engineers but will also be of greater value to process and development engineers who are concerned only with the performance of instruments as it affects the yield and quality of their products. It would give them more assurance that they could present their instrument problems intelligently to a qualified instrument engineer.

MR. IRWIN (Mason-Neilan Co.): I don't know what the ultimate conclusion of the Conference will be, but I have a suspicion that the undergraduate curriculum will not permit courses in instrument engineering. I think it would be a good point to underline the statement that if you teach your undergraduate students the fundamentals of flow you have a pretty basic subject in Instrumentation, whether you are in process temperature, flow or pressure, because pretty well all those jobs go back to fluid flow. So if you teach your undergraduate fundamentals he can get these details later on in these supplementary courses such as Mr. Ferguson spoke about.

MR. UNDERWOOD (Indianapolis Power & Light Co.): Purdue has set up at Indianapolis courses on the college level. I think they give an engineer a certificate which carries no college credit. I know that they will offer any course requested if there are enough in the group that wants it. Some of their teachers are on the Purdue faculty and others come directly from industries in Indianapolis.

PROFESSOR BISHOP (University of Pittsburgh): My conception of this is that too many of us don't know what our graduates will be doing. I think Ralph Webb's talk is very good. When these boys get out of school they don't know what they are going to be asked to do. They may be asked to handle instruments, but if you have a fifth year and call it an Instrumentation course, how are they going to know whether they will need it? Very few of them taking that course would use it after they took it. It is like the fifth wheel on a wagon, I think.

CHAIRMAN MCCABE: I would like to ask the speakers if they have any closing statements to make.

MR. FERGUSON: The underlying thought was not for the universities to develop instrument engineers, but to include enough of a course in instrumentation so that when the man goes out as a chemical engineer, for example, he would know something about the instruments necessary in that type of work.

One other thought. The Instrument Society of America is very appreciative of the work that has been done by some instrument companies in maintenance schools. The general idea was to try to correlate that. One drawback is that the man going to the Brown school learns all about Brown instruments and nothing else; if he goes to Emco he learns Emco and nothing else. I don't know about the West Virginia Short Course but the Oklahoma idea was to learn the flow metering procedures of a number of different companies. That would broaden the base.

PROCEEDINGS OF DISCUSSION PERIOD, WEDNESDAY MORNING SESSION, OCT. 17.

(Discussions of papers by Mr. Young, Mr. Richmond, Mr. Parachini, Colonel Jaeger and Mr. Carpenter.)

CHAIRMAN MINER: Now we are ready for discussion on these five papers. Give your name and affiliation and, if your discussion is more than a simple question, come up front so that you can use the microphone.

MR. EWALD (TVA): Mr. Young and Mr. Parachini brought up the point that motion pictures might be used in education. Both gave as an example the electrical measuring instrument mechanism, but it would appear that the most logical use for that method would be in the study of automatic-control systems in which there is continuous motion of mechanical components, or continuous changes of local temperatures.

Charts and diagrams are very good for static systems, but for dynamic systems the animated cartoons and pictures apparently would be the most satisfactory. The only example I have seen of this method of education was the set of three animated graphs made up by Major Behar, which he used in his lecture at the Gibson Island Instrumentation Conference to show educators how heat flow equations in temperature-control problems can be taught effectively; and his animated graphs worked out very well in making these equations come to life.

Apparently it is in such mathematics that you would have difficulty in stating in so many words how a certain system would work, particularly with dynamic systems, and the motion picture would demonstrate what is going on and where it is going on.

CHAIRMAN MINER: Does either Mr. Parachini or Mr. Young wish to discuss that?

MR. PARACHINI: Definitely the motion picture is very useful in the educational process. I think the fact that schools are establishing film libraries is proof enough. However, the point I made is that there are too many motion pictures; and if you are trying to get across a subject that is perhaps of secondary general interest, the motion

picture will not convey that story and imprint itself thoroughly.

Now the picture is definitely advantageous and probably the best means of illustrating a certain specific mechanism and how it works, to a certain specific group interested in just that one thing. But we are more concerned with a general education, because the electrical indicating instrument is a tool for many people in technological pursuits. Therefore, we aren't sure that the motion picture is the best means of telling our story. Of course I would like to have your opinions: it may be that we can realign our judgment.

CHAIRMAN MINER: Mr. Young?

MR. YOUNG: I have indicated by my sound-slide-film presentation that we think the visual method is a good method. Ours is not a motion picture, however, and of course it might be even better as a motion picture.

MR. SPRENKLE (Bailey Meter Co.): I would like to ask Mr. Parachini if he uses the same scheme in training engineers in the Weston Company as he has outlined this morning for training students?

MR. PARACHINI: Well, substantially, yes, but you must remember that training the engineer for our particular job is more specialized than discussing the use of electrical indicating instruments to all fields. Therefore, the written text and the lecture activity would be combined in a highly concentrated fashion to do this job.

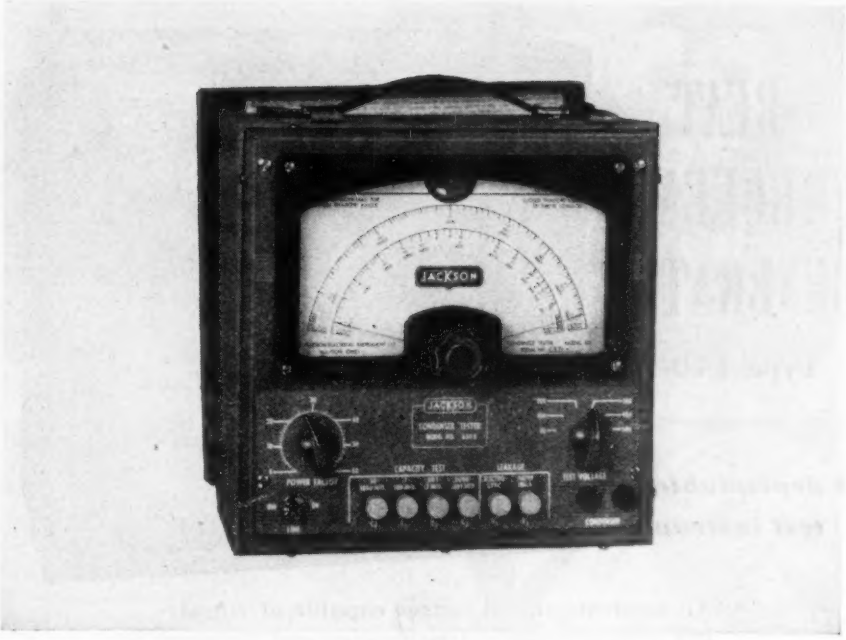
MR. FAIRCHILD (C. J. Tagliabue Co.): I hope Mr. Young and Mr. Parachini won't misunderstand my statement that it was rather painful to sit through those demonstrations—to use our time to look at those films and wall charts—and that in my opinion they are more suitable for training a bench hand than an engineer.

CHAIRMAN MINER: Is there any comeback to that?

Is there discussion on any of the other papers?

MR. PIGOTT (Gulf Research Corp.): I have one comment on Mr. Richmond's paper. If I understood him correctly, he would like to get his engineers trained not only as good mechanical engineers but as instrument engineers. I want to warn him that instrument engineering is not that easy. You find this to be true in the training for the pure sciences. The doctor's or master's degree is valuable to a physicist, because it makes him more useful upon leaving college without experience. Perhaps to a lesser degree the mechanical engineer benefits in the same way, and the instrument engineer benefits very little. In the latter case you are not dealing with pure science and you cannot do without experience.

In our application of technical training we have found that it is advisable to have our engineering and scientific groups in full force, and the best designing is done by a mechanical engineer trained as a mechanical engineer, and if you combine courses it will take



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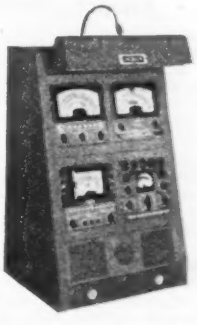

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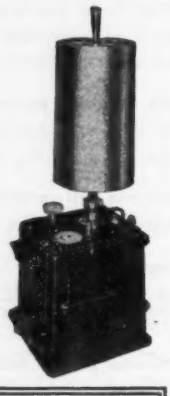

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not four years but six or seven years of training. We have found that we must have a strong mechanical engineering department as well as those with chemical training, and sometimes the arguments between the two branches are extremely beneficial.

MR. RICHMOND: I think the statements just made are correct and I agree with them. My point was limited more to a direct career in the design of electronic instruments. In the company with which I am associated we do have our mechanical engineers in addition to the development engineers. It is quite necessary in the final stages to have the work done by people who have become skilled in what we call mechanical engineering.

There is, however—at least in our own experience—a tendency on the part of circuit men to hold themselves aloof from anything that we might call "practical practice" coming out of the circuit, and they could readily simplify their basic or bread-board designs if they gave thought to how the circuit must operate. As it is originally thought up, a man may be perfectly willing to put one part of his mechanism on the left side of an instrument and something that has to be operated simultaneously on the right hand side, and any old coupling will do, a chain or anything else will do. Whereas if he would give some thought to methods that are common, the standard linkage, the things that he sees when the instrument is completed, he makes himself a great deal more valuable.

I would not expect to have a competent mechanical engineer incorporated in the person of a good, competent research electronic engineer. The two may be wedded, between mechanical and power or electrical engineering, but I doubt if the span could carry over without, as you suggest, taking six or more years; and the temperaments don't go together too well.

But I would like to stress the real importance of an instrument designer in the electronic field, having been exposed to mechanical engineering principles enough so that he likes it.

DR. GORDON (Tennessee Eastman Corp.): I would like to endorse Mr. Carpenter's paper for the chemical industry. Take out "rubber" and put in "chemical" and that would be a good paper for the chemical industry. We need expert chemical engineers, but we also need mechanical and chemical engineers who know what can be done with instruments, not instrument engineers, not men with a doctor's or master's degree in instrument engineering, but what we need is a man who knows what instruments can do for him and knows how they should be installed. If a course in *instrument application* could be put into the curriculum of chemical engineering, I think it would be a great step forward.

CHAIRMAN MINER: Does anyone representing the schools wish to make a statement about the possibilities along

the lines that have been presented this morning?

DR. BROWN (M.I.T.): I would like to speak as a person involved in this educational program. I feel that education is being butted around by very divergent points of view. I listened to one speaker who calls for what I think is work belonging in a freshman or sophomore course and others who would like us to train the technicians in their plants. We can't do it.

I hope that we can discuss this problem in a manner that will permit us educators to take back home knowledge of what you would like us to do. I hope that we can clarify the level on which you want this job done.

There is no more room today in an engineering curriculum for more technical subject-matter. We first must recognize this simple fact. There is room, however—and here is where I take confidence in being able to do something effective—to review the methods of presentation of the subject-matter and inject discussions of these industrial problems into the course as techniques whereby the professor can lend a lot of sparkle to his topic. Tomorrow morning Mr. Campbell will outline for you our philosophy back of teaching the subject of servomechanisms. as we have done it for about five years. It has me fascinated.

However, I don't want anyone to think that we attempt to train servomechanisms engineers or specifically instrument engineers. We would rather that you look at us from the standpoint of injecting into a student's work certain opportunities for him to get dynamic philosophies at his finger-tips, so that he leaves us with a mind that is more fertile, more receptive to new ideas—a mind that may trouble a lot of industrial people because he may often be a thorn in their side and very dissatisfied with the present way of doing things. He becomes a person who realizes that the world is one of dynamics, and life is constantly a problem of change.

The student has only four years in college if he goes only to the bachelor's degree, and all he can get from us is rigorous training in fundamentals. The fundamentals that you people want him to know are the fundamentals of mathematics, physics, electricity, electronics, mechanics. Mechanical engineers should be well-grounded in physics, electrical engineers in mechanics and hydraulics and so forth and Lord knows what else.

The instrument field, as I see it, is uniquely suited as a pedagogic tool for correlating in the student's mind the undergraduate work and lending life to the interrelations between the different phases of engineering work.

As an example of how the implication of an instrument course can change the emphasis on a specific subject, consider the teaching of direct-current machinery. To the instrument or servomechanisms engineer, the important thing is not the efficiency of a motor or

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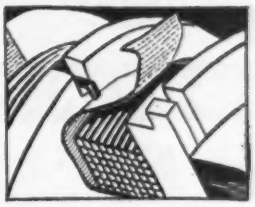

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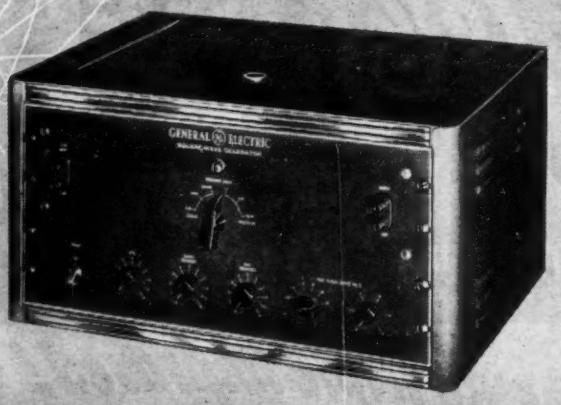

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its speed regulation. Rather t important things are its ability to a celerate, its armature and field time c stants, its weight—for I don't want t carry along any excess mass. It sho l not get too hot, also I would like to know how hot I can get it before it is going to give me trouble. Occasionally, I can completely shatter the morale of the electrical engineering student by showing him a hydraulic motor and saying: "This is good for five horsepower and it weighs four pounds. It has a commutator in it, too; its principles of commutation are the same as a d-c. motor, it has resistance, it has damping, it has inertia, it has a transfer function that I can represent as a real and an imaginary function."

I am willing to work at the problem of instrument education but I think I can only do it at a fairly high level, certainly at the end of the undergraduate curriculum. I would rather do it in the graduate year. I hope I am never tricked into doing it under the pretext that I am going to turn out a specific instrument engineer for the rubber industry, or an instrument engineer specifically for Mr. Richmond because I don't think any specific boy would get a job from Mr. Richmond nor would a specific servomechanism engineer get a job with a particular company.

I think we can use this fascinating subject to correlate our fundamentals of engineering education. We will then have come a long way toward meeting what you people want; and in the last four years I have seen that the subject of servomechanisms has done a lot to vitalize our engineering program.

MR. RICHMOND: When Dr. Brown started out I was ready to get on my feet and argue with him. He has answered the arguments.

What I would like to say is that in studying electrical engineering courses as they have been given in various institutions—and I make no pretense of having covered them all, although I am a member of the E.P.C. accredited group—the coöperative course that we have found given at M.I.T.—five years where the boys work like blazes, it is an all-year-around proposition—is the best-rounded course that I have seen. I don't say that from loyalty to my own alma mater either.

I think the reason the course is particularly good is just what Dr. Brown said: the staff members are always in each other's hair trying to find a better way of presenting fundamentals.

The point I was going to argue with him was that there is no more room in electrical engineering curricula for any other subjects, such as Instrumentation, and he answered that by saying that room can be made available by better presentation. Why the electrical engineering group goes over into the mechanical engineering department to have to learn almost operational techniques, and then perhaps go into another group and learn operational techniques, when the fundamentals ould

all be taught by the mathematics department, is the thing that has bothered me, and I think it has been covered very well.

MR. EWALD (TVA): A number of schools have established courses in engineering physics. They haven't been too popular in the past but the experience has been that this is the best fundamental course that one could take for Instrumentation.

Mr. Carpenter raised the point that there are no Instrumentation courses as such, and I think Dr. Brown brought out very well that it is impossible to specialize to the point where a full-fledged instrument engineer is graduated—all he can hope to take is the basic material—and that the servomechanism course apparently answers that problem very well.

DR. GORDON (Tennessee Eastman Corp.): I think Professor Brown really has something on the ball. I think it is easy for us who have been out of school for 15 or 20 years to forget how long it took us to learn what we learned, and how little, actually can be learned in four years.

DR. BROWN (M.I.T.): May I make one remark that Prof. Jackson instilled into my thick skull, and I still think it is very true: A young man going through college, if he sustains an uninterrupted four years, can become very good at learning the fundamentals. Then, when he graduates, people of industry and society at large broaden his interests and he learns a lot about reduction to practice. But these older educators find that many of their very capable students never add a single thing to their basic professional knowledge after they graduate. Then too, we find that people who have been in industry for four or five years and come back to school, find the learning process very difficult. That is why when the subject of the coöperative course comes up, there is reluctance on the part of the Institute to allow a student to stay out more than one term without going to night school and keeping in practice with the job of studying and mastering new information.

That is why I think it is very important that we in college recognize those things which we can do well—which I think is to teach fundamentals and drive them home as thoroughly as we can. Leave the learning of "engineering practice" till later. Then we should coöperate with industry so that professional development continues when you get these men from us. We cannot do it all.

MR. PIGOTT (Gulf Research Corp.): I am reminded of the book "Calculus for Engineers" written in England about 45 or 50 years ago, written by John Perry. I found in my own case that mathematics and to a certain extent physics teaching was not connected to a practical answer. If you do as Perry did, apply it to a practical matter every time you present a problem, you can hold a man's interest.

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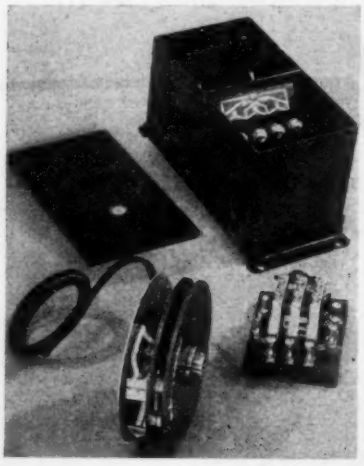

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That was criticized as being undignified, but I think it would be well to give them immediate application step by step.

DR. BERGMAN (Universal Oil Products Co.): I think we cannot emphasize too much that mathematics for engineers is different from mathematics for mathematicians or perhaps astronomers. One of the difficulties with mathematics in most cases is that it is taught by mathematicians. In the few cases where mathematics is taught by engineers it is possible to make engineering applications directly. Even where it is feasible to correlate courses of applied mathematics to the mathematics that has been taken or is being taken at the moment, there is seldom a close coördination because the different books are written by instructors with different viewpoints.

The process of memory usually goes by association; it is easier to remember a song with words than a straight piece of music or a poem. When you have a mechanical application tied up with the mathematics of that application the two are more easily remembered in later years, and those applications are one of the most important things in school.

PROCEEDINGS OF DISCUSSION PERIOD, WEDNESDAY AFTERNOON SESSION, OCTOBER 17.

(Discussions of papers by Professor Williams, Mr. Pumphrey, Mr. Fairchild, Dr. Bergman and Dr. Mouzon.)

CHAIRMAN SPERRY: Before we go on I want to announce that after this Conference is over Thursday, there will be business meetings of the I.S.A. Friday and Saturday at the Roosevelt Hotel. These meetings are open, the same as this Conference. If the I.S.A. can promote such a program as Mr. Pumphrey outlined, I am sure all of the members will bend every effort to get it started. We are very young and you will have to be patient. I was very, very pleased to hear that you are going to help us, because obviously we cannot do this job alone.

A MEMBER: Dr. Mouzon brought out a point which should be more stressed than it is, a point which is quite often overlooked, and that is that we should look at our present courses and see what we can do in getting the material across to the student, rather than trying to add to the course. I think that what should be stressed more is to do away with some of the duplication between the departments and courses.

CHAIRMAN SPERRY: It seems evident that there seems to be a desire for more emphasis on Instrumentation within the existing courses. Particularly in fields like mathematics, there is sometimes a little intellectual snobbishness, in the attempt to remain pure, and I think if we can sell the mathematicians on the idea that these problems of ours are perfectly respectable they will find it to their advantage to learn the tie-in.

A MEMBER: Many of the speakers mentioned the fact that it would be good to have a five-year course. Why not start the students earlier: at sixteen? Many students are capable of handling college work at that age.

PROFESSOR MCCABE: To point up these discussions, perhaps it would be well if somebody outlined the general problem one faces in modifying, revising, or designing an undergraduate curriculum in engineering.

Most of the questions discussed so far come back to a problem of curriculum design. The problem of designing a curriculum is not much different in principle from designing any engineering structure. In both cases you are faced with several realities. First you have certain materials with which to work. In an engineering structure those materials are the metals, plastics, insulations, conductors, vacuum tubes, etc., that you have available at the time. In designing a curriculum the raw material of course is the student that you are receiving.

In general, the engineering colleges are receiving good students. They are not supermen, however, and the amount of training they can absorb in a given time is not infinite.

The second reality we face is student time and the faculty, equipment and so on, that are available. The three realities are, first, the time of the student; second, the size and type of the physical plant and the physical equipment that you can get; and third, the number and type of faculty.

The first one we can't do very much about except doing such things as lengthening the curriculum, but I think we must face the fact that the standard four-year undergraduate curriculum is something we are going to have with us for many years. And remember that actually that is not four years at all; it is about 135 to 138 weeks, which is somewhat different.

We can of course do something about enlarging the faculty; we can do a good deal in choosing faculty men and seeing that they train themselves along the proper lines.

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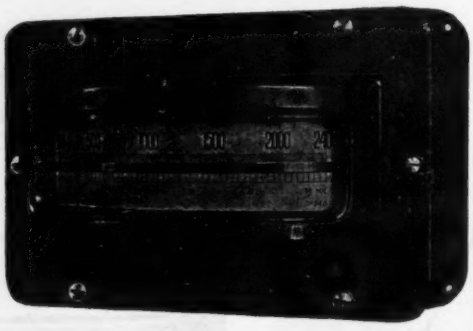

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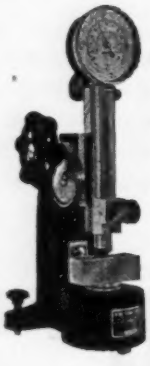

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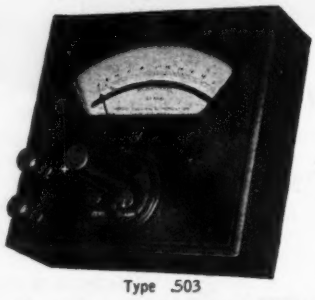

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that structure than you can in a battleship. You could put a soda fountain in a battleship, but I don't think you would put a soda fountain on your destroyer. Let's say you are designing a bomber, and on the other hand a fighter; you can put much more in the bomber than in the fighter. Likewise, more instructional material can be put into a five-, six- or seven-year curriculum than in a four-year curriculum.

We have been discussing the matter of additional courses and some of the suggestions remind one of the good old American custom: If something isn't quite right, let's pass a law! We can change the curriculum and we can put things in, but we would have to eliminate something else that is already there. That is pointing up the argument of the last several speakers, namely, that the best chance of meeting the problem we are faced with is to revise and improve our existing courses rather than add new ones.

I would like to tell you how that problem appears to one who is responsible for the curriculum of a particular branch: chemical engineering. We can do several things in the chemical engineering curriculum now that might help to meet the requests that have been made. First—and I simply want to reinforce remarks made by several speakers: We have courses in our curriculum on mathematics, physics, mechanics, electrical engineering, metallurgy, and chemical engineering. We are giving a good deal of emphasis, as in most all modern chemical engineering curricula, to fluid mechanics. It is important in fluid flow, loss of power in heat transfer, and in the fundamental patterns in which mass transfer occurs in such equipment as gas absorbers, fractionaters and so on. It is also fundamental to Instrumentation, and progress is possible along the line of emphasizing Instrumentation fundamentals in such courses.

The field of mathematics can be used, as has been mentioned several times, to illustrate problems in process variables and their control.

The basic principles of physics should be thoroughly covered in the elementary physics and it is difficult to find anything in elementary physics that is not pertinent to instruments.

Finally, in our own research set-ups, especially in the graduate problems, there is a place where a man with master or doctor's degree should get some background in Instrumentation.

A more specific contribution that I believe can be made in a modern chemical engineering curriculum is this: We are concerned primarily with training students to understand, to engineer, to operate and to design the modern industrial process. That is the central core of chemical engineering training now. We are attempting to emphasize the fact that in the process an instrument is as much a part of that process as is a pump, a tank, a valve, or a fractionating tower, or a heat ex-

changes. There is no reason why we cannot develop courses in processes to emphasize such a viewpoint.

There are some things we cannot do in a chemical engineering curriculum. I doubt, for example, that we can go far in electronics. Work on electronics belongs in courses in physics and electrical engineering; we would not be able to develop a proper basis for such subjects in a chemical engineering course. The same limitation applies to servomechanisms.

So the result will not be an undergraduate trained as a complete instrument engineer, I don't see that that is possible in the single curriculum as we now have it, but at least we can take up parts of it.

The next thing that can be done, at least in large departments, would be to have some elective courses in Instrumentation.

Finally, a school located in an industrial area can aid in the transition between the two phases of technical education, namely, the education done in school and the education done in industry. Let me point out that the education in industry is of comparable importance to that in school. We have a boy in school for about 135 weeks; you have him in industry for forty years. That is a large time ratio. The objective is for the school to give the training that industry cannot give, and for industry to give the training that the school cannot give. That is the principle for allocating those two parts of the same job.

CHAIRMAN SPERRY: That is an excellent summary not only of the question at hand but of many of the other points that have been discussed.

When Mr. Pumphrey said we should combine the study of instruments and control, I was waiting for somebody to add, as Dr. McCabe did, that we should also include the process, because they are all one and the same. The emphasis that Dr. McCabe placed on this point made me think of the definition of a refinery as an automatic temperature controller with some tanks and pipes to connect together the various bulbs, a number of flowmeters, some auxiliary piping, a supply of oil, and pumps to see that the proper flows were provided, and so on, in which the instrument is the focal point and the rest merely the accessory gadgets. That statement is a little extreme, but the trend is in that direction.

MAJOR BEHAR: Our Chairman yesterday opened the discussion period by saying, "Pull no punches in your discussions." I am going to discuss the fundamental term that brought us here, the term "Instrumentation." I object to the phrase "instruction in instrumentation *and* control" used by some of the speakers from both industry and colleges. One of them, my good friend here, even explained painstakingly to us that he advocated that instrumentation and control should be brought together in the colleges—implying that they are

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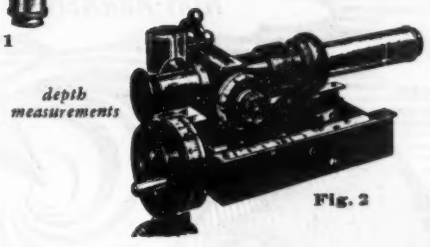

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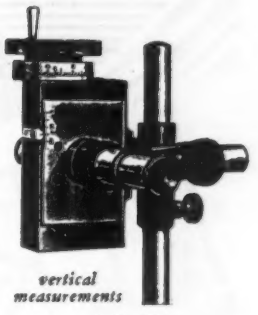

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apart. My dear friend, I take exception to that coming from you more than I would from somebody to whom Instrumentation is quite new and I know that you have been an Instrumentician many years. Well, more than twenty years ago, when the term "Instrumentation" was coined, it denoted "measurement and control" and the first dictum of the then new science that was beginning to be formulated in that dim past was, "In order to control a condition you must first measure it." You can teach measuring instruments without teaching automatic control but when you take up control you can't overlook the need of properly measuring whatever is to be controlled.

One more punch. My good friend here said that he cannot imagine many professors of chemical engineering giving a course in electronic instrumentation; and several other speakers likewise brought up specialization in curricula and faculties as an obstacle. Actually, a number of professors, not only of chemical engineering but of chemistry, specialize *also* in electrical and electronic measurements because nowadays important chemical measurements are accomplished by electrical and electronic methods. I may name one because he is not here and we may flatter him behind his back: Ralph Müller of New York University, a professor of chemistry, not only has taught electronics as part of chemical measurements, not only has designed new electrochemical instruments (he Americanized the Heyrovsky polarograph) but is the author who, with two of his former students, brought out an excellent book on electronics. We have equally versatile educators right here in this room, from industry as well as from the colleges.

MR. FAIRCHILD: Speaking of Major Behar's punch, I want to remind you that there is a lot of control engineering which has little to do with instruments.

MAJOR BEHAR: May I interrupt? How can you control without an instrument?

MR. FAIRCHILD: Mr. Pumphrey can explain that better than I can.

MR. PUMPHREY: I have had a number of arguments involving terminology and the arguments usually end when the terms are understood. Therefore, I am willing to accept Major Behar's criticism of my lack of understanding of the term, "instrumentation." I will defend myself only on the basis that I believe there are a large number of engineers who like myself possibly do not realize that the term "Instrumentation" is so all-inclusive as Major Behar indicated.

Secondly, when I said I couldn't imagine *very many* chemical engineers being qualified to give instruction in electronics, I was trying to emphasize the necessity for coöperation between departments in giving this course. An elective course has been suggested several times. I think it should be not an elective course for the electrical engineers or an elective course for the chemical engineers; it should be a course covering the general subject of Instrumentation and the course should be the same for both. If that kind of course is given, I think coöperation between departments is needed.

PROFESSOR JONES (Northwestern University): It seems to me that one question, which has not been raised, vitally affects the schools. When you gentlemen in industry are engaged in developing a new product one of the first things you do is make a market survey. This question, then, might properly be raised: How many students specifically trained in Instrumentation would you be willing to use a year? And not only for a year but *per* year, for the next ten years?

In electrical engineering at the present time we have two principal options, that of power and that of communication; and although during the last few years the number of students in the communications option has far outnumbered those in the power option, we have every reason for feeling that that balance will be restored. I might raise the question then, can the instrument industry use a number of graduates each year, equal to those absorbed by the manufacturing industries, the electrical manufacturing and the power industries or by the communication industries?

It seems to me that some information along that line is of vital importance to the schools before they can reach sound conclusions as to what steps they should take in this particular picture.

The discussions that have been presented yesterday and today have ranged all the way from an increased emphasis on instrumentation in the present

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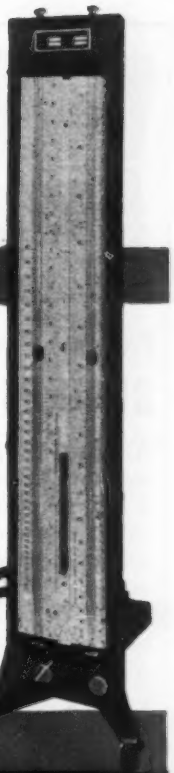

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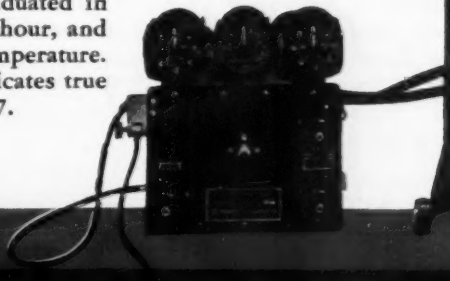

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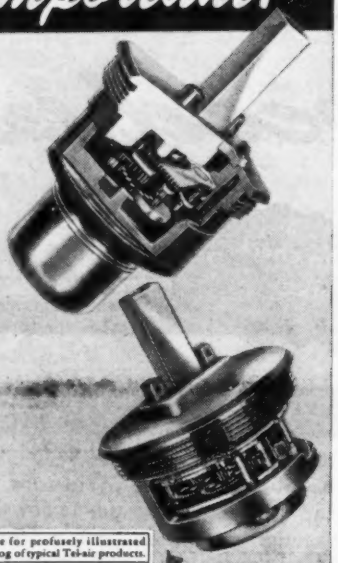

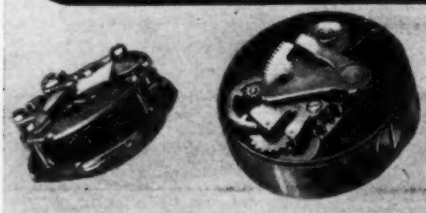

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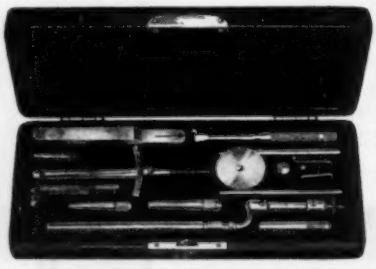

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courses; that is in physics, chemistry, and in engineering, to what I gathered to be completely new curricula involving a vast array of courses which apparently for the most part excluded those standard courses which we have come to accept as part of the usual engineering curricula.

The question may well be raised, if such a completely new curricula were developed, such as Mr. Pumphrey just suggested, in instrumentation presumably cutting across all fields, electrical engineering, mechanical engineering and chemical engineering, would the graduate trained in such a curriculum be equally satisfactory to a power company, to a rubber company, or to a steel company? It seems to me that if those of you representing industry, and possible employers of such men, could give us an answer it would be of help.

MR. ACKLEY (Republic Flow Meters Co.): On this matter of instrumentation *and* control, Major Behar, where would you classify a lot of liquid level controls which have no instrument associated with them at all? Also the complete combustion systems Republic manufactures with no instrument connected with them? And take a turbine governor as a controller, it has no instrument at all.

SEVERAL MEMBERS: It has . . . [etc.]

MAJOR BEHAR: You see, the last question you asked was answered by the audience's reaction, so that part of it is settled. Now if you had worded your question—

MR. ACKLEY: What then do you mean by an instrument?

MAJOR BEHAR: That is not the question you first asked. You wanted me to classify a non-indicating liquid level controller. It is a control instrument because it has a measuring element. Even in the kind in a water closet—a crude example—the ball float and lever perform a measuring function and command the valve. Since instrumentation began to be formulated, it is the steam trap, rather than the level controller, that has been called the dividing line between "fittings" or "devices" where no measurement is performed, and "instruments." But I think we should cut this short.

CHAIRMAN SPERRY: That's right, let's not get involved in that.

MR. FAIRCHILD: It has seemed to me in listening that some faculty members have had in mind taking rather complicated instruments into their courses of instruction. In my opinion, recording instruments and recording controllers should not be used in undergraduate instruction, and to only a limited extent in special post-graduate courses. The subject of automatic recording doesn't involve any basic theories that are different from automatic control and in the matter of instruction what is the difference between a recording controller and a controller?

So I would like to suggest to the teachers contemplating using instruments in laboratories and lecture

courses that they think of the theories of measuring and their relation to standards of reference. The principles that are common to other sciences can be demonstrated best from simple instruments and non-recording controllers.

Recently there appeared some information on a set-up in Washington University of automatic control. Without appearing to be jealous of a competitor, that apparatus is entirely too complicated to be taught to students, it was made of circuits and leads that are incidental, that are not essential, and there are plenty of simple devices.

The principles of physics can be demonstrated on the lecture table by an instrument rather than a home-made device, for example. The mathematics lecturer can demonstrate why he is teaching mathematics and leave out these difficult and complicated matters. I tried to use the word, "instrumentology," to indicate that you cover all the fields of instruments and that you can teach the principles of instruments.

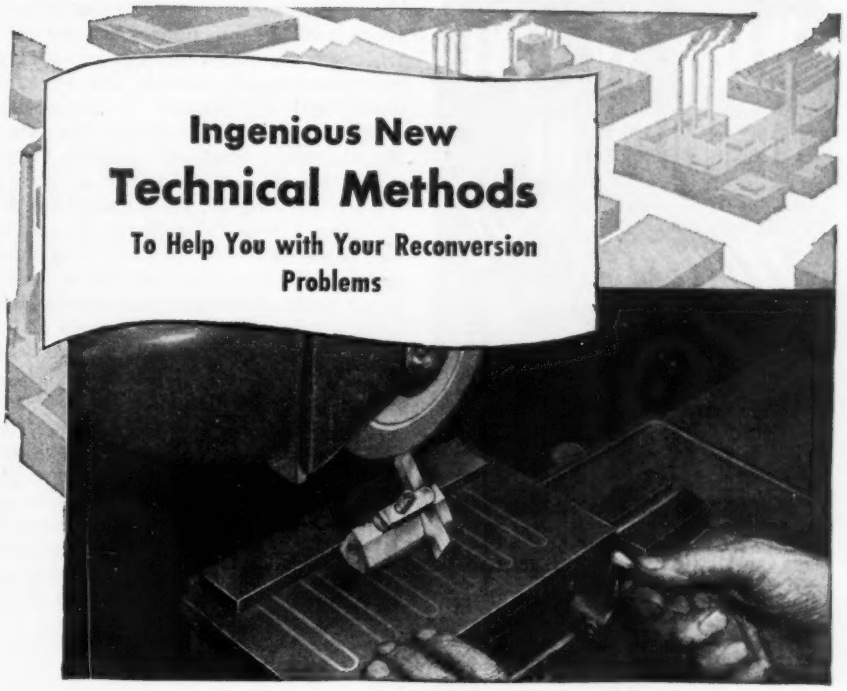
DR. GORDON: I believe Professor Jones has asked a very important question and I would like to answer him by saying that it would require a very large chemical company indeed to require more than one highly trained instrument engineer in its entire staff. But we do need many chemical engineers who know how to use instruments, having gained their knowledge through just such a course as Dr. McCabe has described.

A MEMBER: The gentleman's statement is all right, except that the highly complicated industrial process is going to increase the need enormously. It is quite true that the large organization probably will hire only one for the time being, but as time goes on we are going to see more radio tubes and more instrument engineers. Contracting firms are highly interested in instrument engineers. Instrument companies themselves take it from another angle, they prefer to talk about the ones they build, so we may expect that they would like to take the green material and build it themselves.

PROFESSOR CEAGLSKE (Washington University): I would like to say a word or two about the set-up we have at Washington University. I happen to be primarily responsible for that, so would, therefore, be pleased to have any suggestions for improving it. Mr. Fairchild's remarks are welcome. Our set-up was made primarily to show undergraduate students how these controls react. Experiments with this equipment are part of the regular Chemical Engineering laboratory work. We do not expect the students to know how the instruments operate.

I was very much interested in Professor McCabe's discussion. I think that control is as much a part of chemical engineering as fluid flow, distillation and some of the other things which we normally take up in the course.

We have no special courses in instrumentation for undergraduate students.



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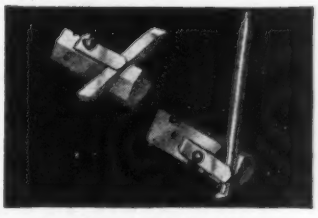

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We do give such a course in the Graduate School. In our undergraduate laboratory work many types of measuring instruments and controls are encountered, and are studied in connection with the experiment involved. The paper Mr. Fairchild mentioned may be found in *Chemical and Engineering News*, Volume 23, July 25, 1945, page 1245. In that paper you will find that we have the three types of control: the two-position, the proportioning and the automatic reset—both air- and electrically-operated. In addition to the make of instruments listed in that paper, we have the Foxboro—and, yes, Mr. Fairchild—we have the Tagliabue!

MR. IRWIN: May I say, in answer to the question of the gentleman from Northwestern, from the viewpoint of the Engineering Departments of several instrument companies, I know that they all would like to be able to hire some design engineers. I know from the sales end of the instrument work that there are many available sales openings. I can say also that one of the standard questions as I go around to the various instrument-using companies is, "Do you have anybody you can recommend for our Instrument Department?"

It is impossible for any single individual to say quantitatively how much demand there is for instrument engineers as such, but broadly speaking, I think it may be called "large" and, percentagewise, the number is going to increase as time goes on.

One of the large chemical companies that I have had occasion to work with over a period of years makes many management promotions from the Instrument Department, because this is the only group familiar with the operation of the entire plant. The successful instrument engineer is the one who knows the processes to which he applies his instruments. That is why I assert that the demand for instrument engineers is going to increase.

A MEMBER: I don't think the professor had reference to the finished engineer but the engineer who was going to be engaged in some certain line of work. It seems to me that very few industries wouldn't take that type of man; there are very few industries that the instrument man can't call on.

A MEMBER: The average plant nowadays has an instrument installation somewhat equal to the electrical equipment, and from that you can assume that you will need as many instrument engineers as you will electrical engineers. Likewise, so far as the operation is concerned, you may need as many instrument mechanics as electricians to keep the plant in operation. This is becoming appreciable nowadays; ten or fifteen years ago you could say that all the instrumentation the average plant had was two gages.

CHAIRMAN SPERRY: Some of the apparent confusion that was mentioned yesterday and this morning is due to the fact that we are talking about more than one problem. We must have trained instrument designers; we need physicists who really know instruments and have been trained in instruments and control theory in much greater degree than before; we need engineers all through industry who are well-equipped in using the methods outlined by Dr. McCabe; and we have to have maintenance men. And I probably could classify them farther. The colleges cannot train one man to be all of these, in one four-year curriculum, but the hope here is to develop a train of thought as to what the colleges ought to emphasize, first, in their undergraduate and next in their graduate work.

I just looked up how many Ph.D.'s have graduated in the United States: in normal years there were about 800 a year throughout the whole country, in the physical sciences. Of those 800, very few have had real specialized training in Instrumentation — and this is not healthy. Now, nobody expects that this Conference is going to end up with I.S.A. or any miracle organization handing us these instrument technicians on a plate. But we have to develop a trend, so that out of meetings like this, more of that type of education will be encouraged. That is the only thing that you can hope for as an immediate result. Ten years from now, we hope, that tendency will have developed into a full-fledged instrument technology in a number of universities, and I think those that follow the instrument field, those that have watched closely, feel that by that time industry will be able to absorb any practical number of instrument Ph.D.'s that are likely to graduate.

PROFESSOR JONES (Northwestern University): Before the discussion gets out of hand on my question, let me say that it was raised to develop discussion on a rather important point; and I think it has worked successfully, because it has brought out a number of ideas.

It has brought out one idea which has come up several times before. The gentleman back here brought it up just a minute ago. When promotions were to be made they were made from, in this particular case, the Instrument Department because the men in that department were familiar with the entire process involved.

We do not want, and I am sure you do not want, instrument engineers who are not familiar with the fundamentals of the process, whether it be an electric power plant or a rubber plant. It means that in developing individuals with such specialized training—and here I will refer again to the electrical engineering curriculum—those individuals are going to have to have just as much work in power plant machinery or electronics as they now have, and the training in instrumentation is going to have to be added to their present curriculum.

DR. BERGMAN: Along the lines of Professor Jones' question, I might indicate first that we have had the problem of designing a large number of aviation gasoline plants, with a group of, say, 25 chemical engineers involved, who

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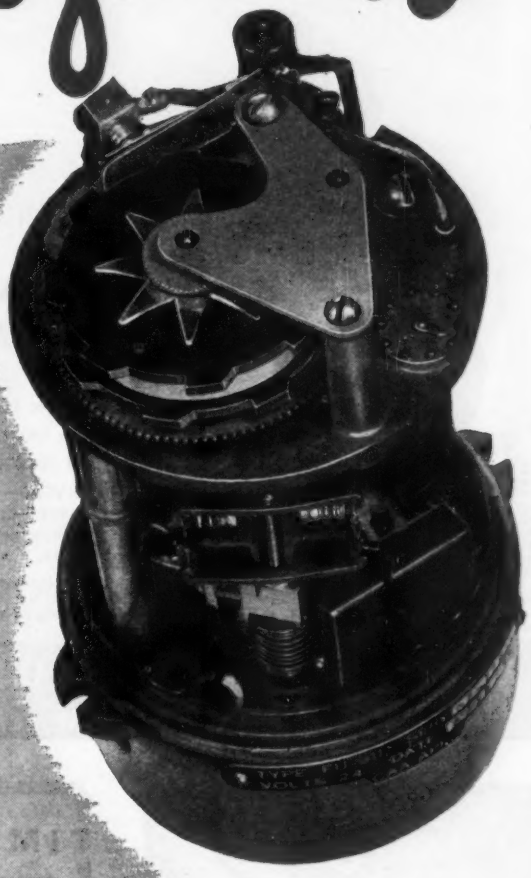

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should have been more familiar with instruments than they were. They had some familiarity through flow-sheet conferences at which members of the Instrument Department were present. And changing the process to make the instrument work a little easier was not just a theory: we did it!

Following that period came the problem of putting those plants in operation, and we had close to 90 men, practically all chemical engineers, out supervising the starting up of operations. There wasn't one of those men that could not have used a large amount of instrument technology. Most of them didn't have it.

Just before this period of operation started we sent a small group on a tour of a number of instrument companies. They came back with totally new ideas of what the process did with instruments on it, simply because they had been around to some of the instrument companies who developed these application theories, not just the means of maintenance of instruments and adjustment of instruments, but how to adapt the instrument and its adjustments to the process.

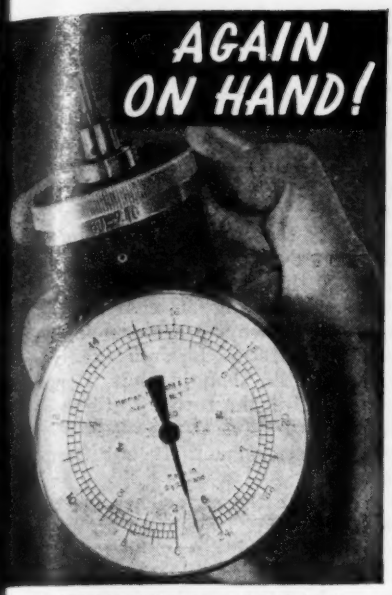
Answering the question then as to how many men with fundamental instrument training would be required, I would say first, every chemical engineer, and I don't see where you are going to lose out at all by giving this training to electrical and mechanical engineers. So I think that is the answer.

One more thing. These engineers would know a little about instrumentation. During the design period mentioned, we had about five or six men who were writing instrument specifications and working out special applications. If you are talking now of the graduate engineer who has been through the finer points of Instrumentation, maybe that is something like the ratio, five out of 90, or 6%.

CHAIRMAN SPERRY: I see Hanson of Du Pont shaking his head as if he agreed with you on that experience. It is drawing close to the time when we should adjourn, but I saw Dr. Brown's hand up and I think it would be fitting if he had the last word.

DR. BROWN (M.I.T.): Is this the last word? I perhaps take a different view of this problem of Instrumentation from some of you, because I believe that "Instrumentation" and "control" are synonymous educationally. I would like to state that I think a special course in engineering schools can teach the fundamentals of Instrumentation without speaking of a specific physical condition, because the basic principles of the problem are common to all applications.

A control system is a feed-back system, the response in answer to a stimulant is fed back to the front end of the mechanism and thereby establishes a regenerative process. The system, as I look at it, comprises an array of instruments. There may be an instrument that converts light flux into volt-



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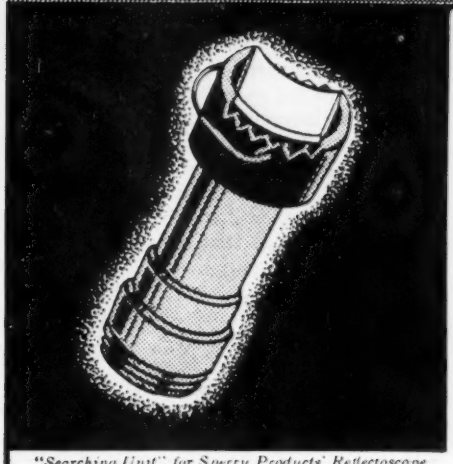

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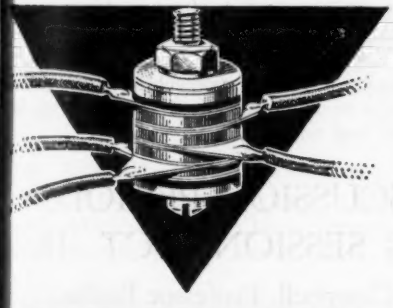

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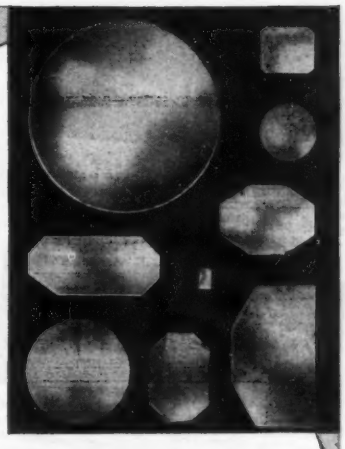

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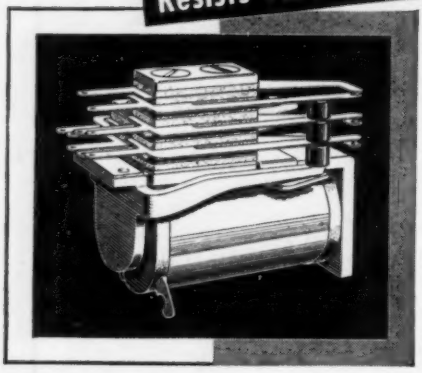

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age; there may be an instrument that converts voltage into torque; there may be an instrument that receives a torque stimulant and causes acceleration of a mass that may be a steam valve in a speed governor which throttles the flow of steam to the prime mover. The prime mover can be looked upon then as another instrument which can exert a change in its speed. It has a certain dynamical behavior. Its speed has to be measured by another instrument and the result of that measurement process is fed back to the primary measuring element, which may be the 60-cycle reference that we want in this power station equipment. Therefore, you transgress over a wide field in any simple demonstration. You introduce thermodynamics, physics, electronics, and so forth. But you need not go into details of those elements if you are only going to discuss the fundamentals of Instrumentation because you need merely to impress upon the student that all equipment involves storage and energy dissipation, that each element can be assumed to be a small box in itself: a signal goes in and at some time later a response comes out. This condition can be expressed mathematically very well. You can then write the complete equation for the whole assemblage of apparatus, you lead the student through the mysteries of differential equations, and then you put him to bed very gently and tuck him in if you give him a time solution for say the transient speed change due to the application of 1000 kilowatts at the output of the generator. Only then do you become specific.

As I see it, instrument and control problems can be potent as educational tools in all departments, regardless of whether the problem relates to chemical engineering in the process industries of oil or rubber, or aeronautical engineering or mechanical engineering. The process itself in my definition is just one more instrument, and if you instill in the student's mind that he is synthesizing a system which is to give him a prescribed performance, he may come up one of these days with the question, "Let's go over and talk to the boys who designed that tower and see if we can't get them to change its characteristics." Instead of always attaching an instrument to a process I would like to leave with you the thought that it may be economical in the future to think of attaching the process to a new and novel type of instrument. It has happened before.

I can cite the experience in the aircraft industry. If you let an airframe designer have his way he may design an airframe with a stability similar to the Rock of Gibraltar and you can't put a control on it. What you want is a harmonious balance between the airplane dynamics and the automatic-pilot dynamics so that the airplane flies comfortably for the crew and passengers. The control engineer, as I see it, becomes more and more important in the industrial set-up because he becomes one of the few who realizes the significance of little things here and there throughout the entire system. In other words, he is concerned with the problem of how the elements integrate together. This feature can often attract good men to industry and offer opportunities for attaining a high level of authority and rank within an organization.

For these reasons, Campbell will say tomorrow that servomechanisms courses have unusual pedagogic value. This is the last word tonight.

PROCEEDINGS OF DISCUSSION PERIOD, THURSDAY MORNING SESSION, OCT. 18.

(Discussions of papers by Mr. Campbell, Professor Beitler, Professor Miller and Mr. Hall.)

MR. MCMAHON (Republic Flow Meters Co.): I would like to raise the question of whether anything as highly specialized as instrument engineering should be introduced in engineering courses at all, whether it has any fit place in the training of a real engineer.

That comes up in two or three different aspects. The first one is whether it is possible to include anything as specialized as that and get any adequate benefit from it, and at the same time give the man the really adequate engineering education that he needs, as stated by Professor Beitler. I don't believe it is, myself.

It is amazing to us who are concerned with both obtaining manpower in our own companies and giving instruction to men from customer companies, how many men there are with engineering degrees who know nothing whatever about anything except their own little specialty.

So from my own angle, the thing that educators can do better than anything else is to produce men with a better understanding of physics, chemistry, chemical engineering, thermodynamics, mechanics, and those basic things that should be known to engineers.

However, the second thing is something which has been my hobby for some time, something else mentioned by Professor Beitler and largely discounted in engineering schools, and that is that most engineers are not good citizens. I say that advisedly. Most engineers have no conception whatever of the implications of history. Most of them have no conception of the effect of what they are doing today on current history, and that is

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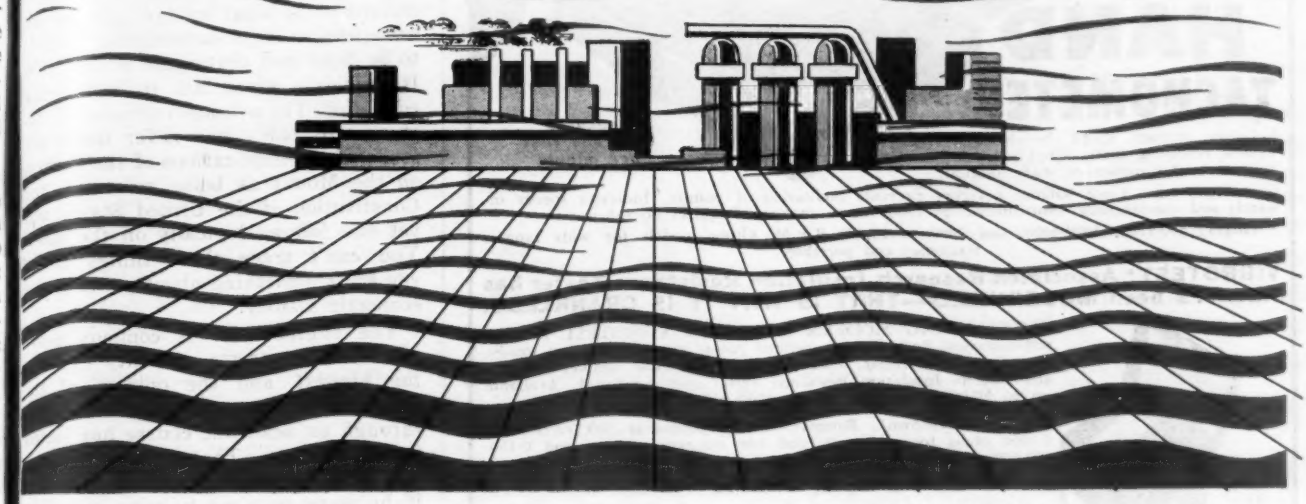

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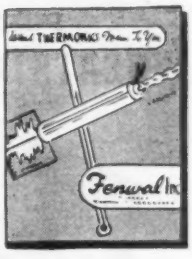

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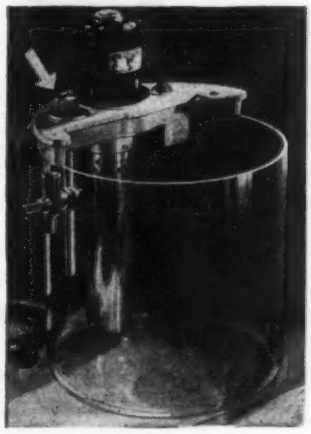

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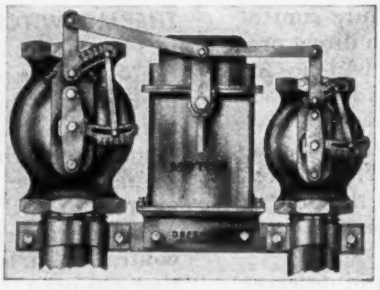

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shown by the current discussion in Washington on the atomic bomb. The scientists are speaking up, but there is no attention paid to them, and that is going to be politically settled.

We are responsible. We have never made ourselves prominent in political affairs. Most engineers have a narrow viewpoint and little understanding of the significance of current happenings. Businessmen and lawyers have studied those things and they are running the country. They look upon us as technicians to do what we are told and not have any voice in determining what is to be done, and that again is our fault. It implies a great lack in engineering education. The average engineer, for instance, probably has never made any study of the implications of the Sermon on the Mount as being related to the Constitution of the United States, and yet one follows logically on the other. You can't trace those things unless you know something about political and economic history.

The engineer, it is common complaint, has extreme difficulty expressing himself, and the opinion of the engineer is that the man who goes through an academic course has loafed through school. That is not true today. The engineer would be resentful if he were required to turn in a 500-word or 1000-word theme every day, and yet he would be better able to express himself and would be a better citizen if he had had that requirement.

Considering the implication of those things, I should like to raise the question of whether engineering education has any place for anything as specialized as Instrumentation education. It is my opinion that the courses which could be better introduced into the curriculum are courses in liberal arts.

Let me point out one mistake that I think the colleges have made in that connection. The colleges have not had, for their courses in English and other liberal art subjects, instructors who were of the first grade. You have to have a man who is a master of his subject to hold the attention of men who feel that such a thing has no place in the life of a real honest-to-God heman engineer. It can be done; first-raters will do it. Second-raters won't and the engineer will come out with no mastery to express himself to the general public. As a specific example of the things I speak of, I gave an example of the atomic bomb.

Second, I should like to know how many men here, for instance, have read "The Road to Serfdom," and yet that is the only important book on economics that has been written in 40 years. I doubt that very many of us here have read it or grasped its implications. Yet an engineer, particularly an operating man, a fellow who has had very much experience with industrial processes, will grasp the implication of what that author is trying to say better than anybody else, because he is talking about the auto-

matic correction of the economic system by competition. Every one of us knows what that means if we have had any experience in industrial processes.

We have to start thinking that way and get the things we lack. We can't do it if we are relegated to the role of merely slightly superior mechanics, or technicians.

PROFESSOR BISHOP (University of Pittsburgh): Speaking of the experience we have had in setting up courses in Instrumentation, we went to the industrialists of Pittsburgh and got Mr. Pellettere of the Gulf Oil Company to give our course for us. In the last four years he has given ten or twelve courses. We have had research workers from the Bureau of Mines on high-pressure work. This semester for the first time he is giving a course open for graduate credit and we had 53 graduate students enrolled, showing the interest on the graduate level.

I would like to have Mr. Pellettere tell you a little bit about the course. We have had a great deal of coöperation from the instrument men; they sent 200-pound boxes of literature to our office to be presented, and so on. Mr. Pellettere.

MR. PELLETTERE (Gulf Oil Co.): I feel sure that Mr. McMahon meant the four-year, 135-week period, and it seems difficult to fit extra courses into this period. I do feel, as Professor Beitler stated, that fifth-year work is the only place for instrument study courses.

The hunger among graduate students in the industrial instrument line indicates that such fifth-year classes will have high-grade students.

I say in each case there is a method of justifying whether or not a company is in need of an Instrument Engineer.

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We know instrument companies can use graduate Instrument Engineers, but again, I feel that they would rather have green men for research work, since their patents limit work to a definite pattern and they would rather have new men work accordingly.

In 1942 we started giving courses and we drew everything, from an A. & P. boy who wanted to do better, to graduates seeking more data. As we went into the second course there were something like 32 students left. We later gave a short course in electronics as applied to six or seven commercial instruments, in an attempt to explain radio tube application in a simple manner.

MR. SPERRY (President I.S.A.): I would like to bring up another question that I would like to hear a little more

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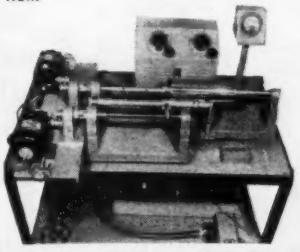

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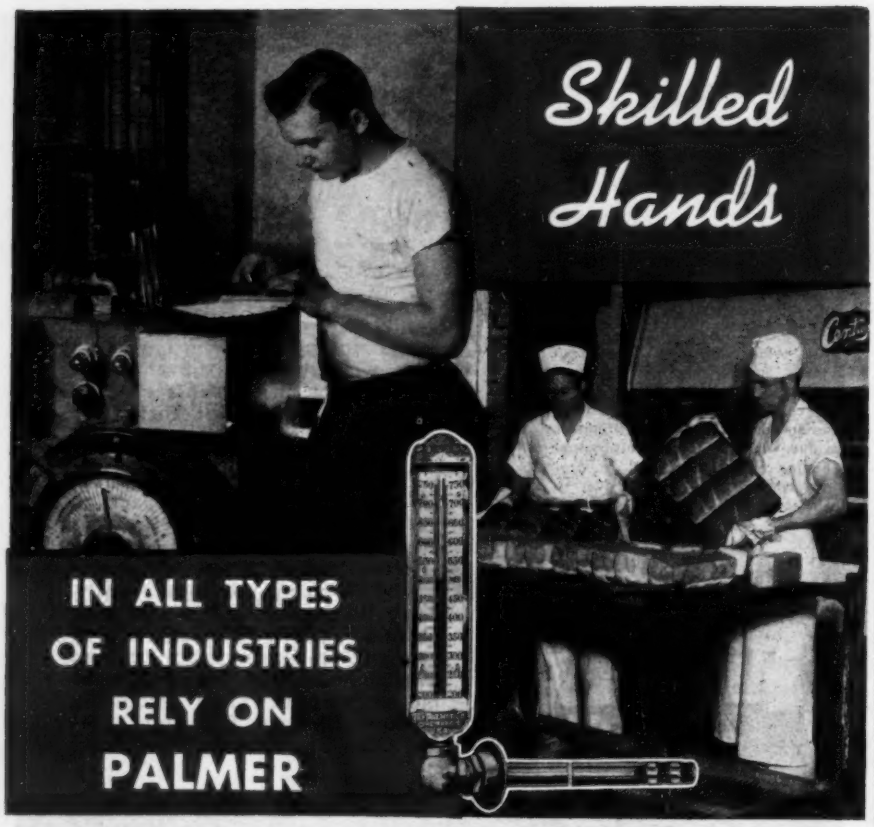

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about: on the question of the university curriculum. Taking up McMahon's point, which was somewhat raised by Beitler and others previously, there are many other things that we could criticize if the heading of this conference wasn't "Instrumentation." However, referring to Campbell's talk about the servomechanism group, I am not entirely clear whether M.I.T. have any plans to include any of this material in undergraduate work and I would like to hear some comment from them on that.

MR. CAMPBELL: We have worked for approximately five years developing a graduate program in servomechanism theory and I firmly believe that the essence of the teaching that we do now in the graduate school can serve as a guide for teaching in the undergraduate school.

I do not believe that specialized Instrumentation and servomechanisms theory can be taught in the undergraduate engineering school program. I agree with Mr. McMahon in this, but what I claim as the great value of the servomechanisms approach as we have taught the subject is that a proving ground for engineering is provided by this type of course. It is not important that you should teach servomechanisms theory or Instrumentation theory, but it is important that you get down into the undergraduate level an idea of correlating, bringing together, at the termination of a man's undergraduate career, the concepts that he has learned in mathematics, mechanics, physics, chemistry and the like. I feel very convinced that we are doing this now with the graduate students. A new program will begin in November, consisting of a professional elective course in automatic control principles primarily intended for undergraduates. The course content will not be servomechanisms, it will not be Instrumentation, it will not be process control, but it will include some discussion of all of these subjects as an interesting means of tying together undergraduate engineering training.

We hope the new course will be a place where a man can find new and interesting methods of applying calculus, new and interesting methods of using mechanics, a new and interesting way of looking at electrical machinery. Finally we hope to develop in the students an aggressive course attitude for carrying on their own education, whether they go on into the graduate school or whether they go into industry.

MR. MCMAHON: I would like to make a remark about that also. I think the feeling of the instrument manufacturers is that they prefer to get as men for their engineering departments, or application or sales engineering departments, men who have had some actual experience in operation in industry, preferably in rather complicated processes, because from our standpoint we find it a great deal easier to make concepts of automatic control clear to men who have already had some feeling of how the process acts, rather than to first train men to understand how processes act and then go into instrumentation. I think those who are hiring men will agree that it is much more difficult to do both types of training.

Also I might make this remark to Dr. Miller as to what you can put up as laboratory equipment. Don't set up processes, set up simulated processes. One of the most helpful things in the world, and one of the things the customers' men like better than anything else, is to work on some simulated process without burning the whole plant down around their necks. The man can't do that in his own plant and that is perfectly fascinating to him, because particularly the men who have been out doing instrumentation work have been wanting to try it, and then the production superintendent comes around and says, "What are you doing here?" and then they have to quit it.

A MEMBER: I have been suffering from inhibitions due to ignorance: I feel with Dr. Brown of M.I.T. that there may be some misunderstanding on definitions. Mr. Hall seems to think that in the undergraduate course we might be able to give a man his tools, and he goes so far as to say: so that he can manipulate the machinery and take it to pieces and see how it works. That is a tough assignment.

I know that the General Electric and Westinghouse people have men with

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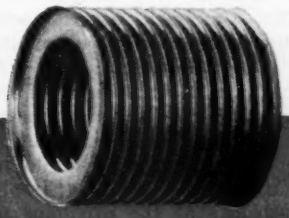

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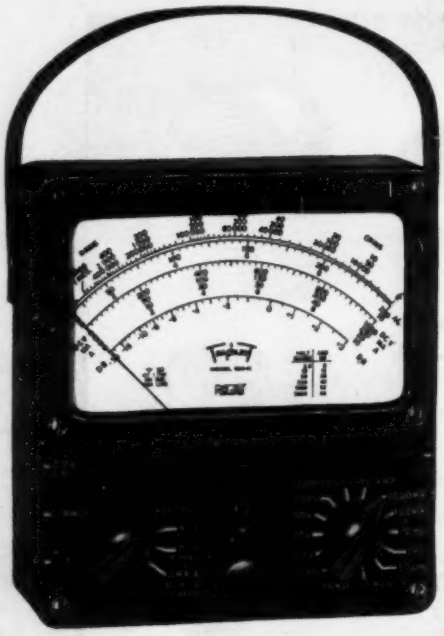

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years of experience to come around to tear the thing to pieces, and I am sure that General Electric and Westinghouse feel the training they have given these men was part of their duty, not a part of the duty of the college.

In our basement we have very complicated machinery and mechanisms, costing thousands of dollars, and I don't think I am misquoting the Taylor Model Basin when I say that they prefer to get a man with good fundamental training and later give him specialization.

As for public speaking, I have wished I had more, but if we try to give companies all they want in educated and trained graduates, we will have not a five-year course but a six-year course.

PROFESSOR JONES (Northwestern University): I would like to take just one or two minutes to develop an idea which I think Mr. Campbell mentioned earlier this morning, and one which I feel is most important in any engineering training. Mr. Campbell has already mentioned the function of servomechanisms as an integrating factor in a college career. Such a course also offers the possibility of developing the synthetic approach, which I admit is lacking in about 90% of what we do in college. What I mean by that is simply this: If one looks at the problems in textbooks, most of them are artificial situations in which one has to come out with a number, that is the answer. In only a very small percentage of those problems is one faced with a typical situation, that of designing a system or a machine to achieve a given objective. I think that control or servomechanisms is an ideal subject from that standpoint, in that it enables the student to set up a system, predict the results and check his results quantitatively.

But I would also mention at the same time that if a course so handled is going to serve its purpose, it must be done on a thorough quantitative basis, and that a purely qualitative discussion of apparatus and their performance will not train the student to face a problem and create a solution, either on paper or partly on paper and partly in the laboratory.

MR. PIGOTT (Gulf Research & Development Co.): From the conversations so far it seems we can sum up the results of this Conference as confusion as to whether you are going to be able to turn out a completely finished and polished engineer after a certain number of years of education, or not. There are at least two principal factors which must be considered. Up to now, we have discovered, we are not turning out such an animal, and that experience is essential in any line of specialization. The thing that has shown up plainly is that not enough of the fundamentals are taught in the college courses so that the man placed in a situation can specialize readily.

Let's say the average student has intellectual capacity, perhaps 20 years

old, and that he can get a certain amount of knowledge in four years and you can't pack any more into his head than that. All you are doing in college education is, you hope, to equip him with a fine set of tools for work and you hope also to have encouraged him to use his own mind without outside stimulus. More than that you cannot do, and you can at no time replace experience, even in the purest scientist.

The fact is that if you have only a limited time and limited mental capacity, you ought to put the basic stuff in first and whatever specializations you have time for at the end of that, whether it be teaching in history and culture, as Mr. McMahon said, or teaching servomechanisms; these should be left to the end, when the student is supplied with basic material but some time is left. And the man who employs him will have to hope that he will continue to educate himself.

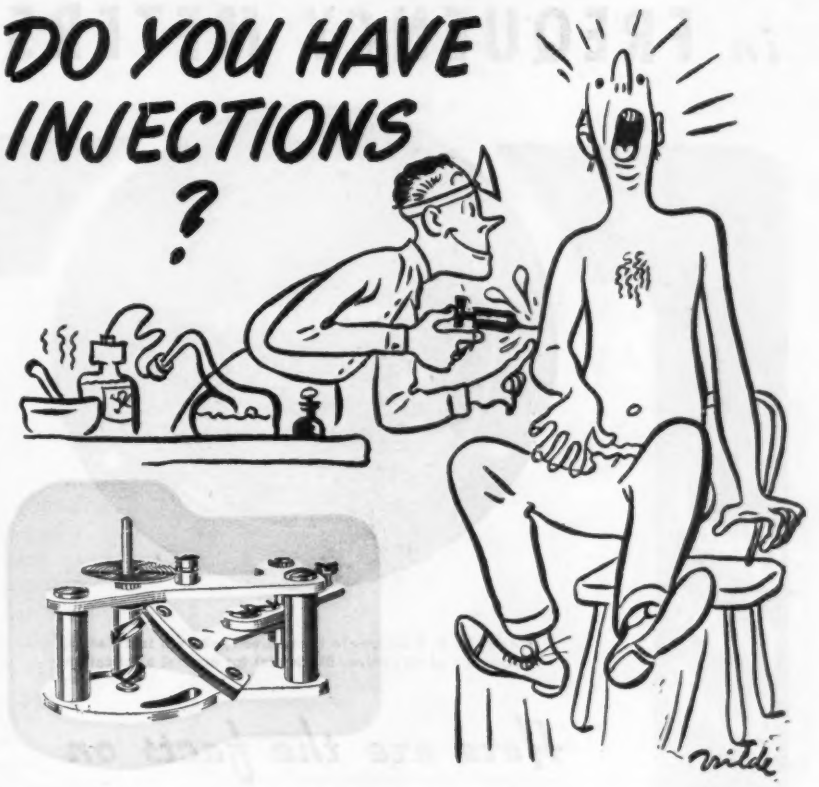
One cannot escape these facts. It is shown plainly in this Conference that we are asking the colleges to do too much within the time and intellectual limits.

MR. SHERMAN (Student, Carnegie Tech): I would like to ask why the student engineer should have specialized courses in Instrumentation if there are so many types of instruments in even one field that it is impossible to become acquainted with any but the most basic, since the branch of engineering—research, development, manufacturing, processing, or sales—into which we will enter will depend on the job we will get when we get out of school? It seems to me that the years at college should be used to give basic knowledge, and in the light of these discussions, does it seem reasonable to have specialized courses in instruments?

DR. GORDON (Tennessee Eastman Corp.): I would like to emphasize what this young gentleman brought out, and would like to pose this question: After all, how many of us in this room—and each one can answer for himself—is now working in the line in which he specialized in the university?

MR. MCMAHON: One of the aspects of the question is the matter of ethics. It is supposed to be fundamental that engineers have professional ethics. I don't know how they acquire them, there is nothing in the engineering course that even tells them what professional ethics are, in fact, there is considerable argument on whether engineering is a profession.

PROFESSOR WILLIAMSON (Carnegie Tech): May I say something about fundamentals, including English. As a teacher of one of the fundamentals I should like to put before you the idea that no one learns the fundamentals by going to classes on fundamentals. It takes meditation. You have to put those things on the back of the stove and let them simmer for years. You expose the student to some training in fundamentals and then you hope that in the upper-class courses the funda-



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mentals will be continually emphasized and brought out, and that the upperclass instructor will show that he is using them.

Isn't it the same with English? My three children haven't learned to read or write; that is up to the schools, not the colleges. Maybe some day they will know how to read and write. Perhaps it will be because they go to college and the college instructor, amongst other things, insists that they read and that they write. He is working on those fundamentals, showing they are useful and exacting standards all the way along.

I don't believe that the type of course in pre-engineering education is badly chosen at all. Even though I teach a fundamental, I don't care if no more time should be devoted to it, but what I want very much is this: that no matter what the upper courses may be, the instructors in those courses will continue to emphasize and demand efficiency in the fundamentals. I don't think it matters very much what an engineer's college specialty is; the important thing is that the fundamental things should be continually, conscientiously used. Then whatever he turns to later on, his mastery of those will grow. It won't be complete, not if he lives to be a hundred, but it will be better all the time.

MR. WILDHACK: One of the reasons I urge so strongly giving a survey course to all students is just the thing that the student pointed out, there are so many instruments and they are from so many diverse lines. This student doesn't know just exactly what line he is going to get into—though when he does get into it the chances are that a very considerable portion of his work will be related to instruments.

This is true and getting more and more true in all lines. Is it not therefore reasonable to believe that he would be better equipped in whatever line he gets into if he has had at least a passing acquaintance with the fundamentals of Instrumentation, or perhaps, I should say, a course in "Instruments—Their theory of operation and their application"? In studying the *application* of instruments the student will get an acquaintance with all the other lines in which he may find himself, even though they are not closely allied to what he thinks will be his specialty. I argue here not for a specialized course in Instrumentation but a generalized course in Instrumentation for the general practitioner.

I believe firmly that we should have some courses in Instrumentation in the physics department. But after all, physics is the mother science; when you get it out to the art of applying that science it becomes engineering. So I think one of the big problems the educators have is the problem of giving this wide survey course to junior or senior students in all of the branches of engineering.

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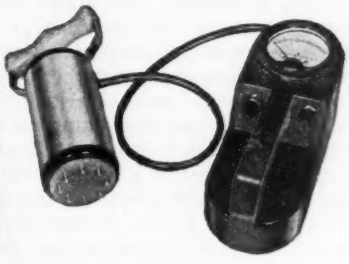

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INSTRUMENTS AND MAN

(Continued from Page 759)

with their international outlook and tested knowledge must put their shoulder to the wheel. But time is short and the sooner the better. For instruments have revolutionized not only mankind's senses but also its power to act.

Naked thought is helpless; even to communicate it requires the verbal instrument of language and to record it and spread it requires material tools. From chiseled hieroglyphics to inked parchments to printed books to teletype and radio, instruments have increased in efficiency of performance and the power of ideas has multiplied in consequence until they can topple kingdoms. The pen has truly become mightier than the sword.

But material power has increased as well as the power of ideas. Instruments turned horse plows into bulldozers, horse carts into air clippers and horse power into atomic power. Instruments revolutionize not only our concepts of time and space but also our control of them. Even before the atomic age, each man commanded, in this country, an average of 13 horsepower. And the atom bomb is more powerful than the pen, as the panzer divisions had become for a time more powerful than the truth.

You have read in recent weeks the statements of the Association of Atomic Scientists, who developed the bomb, and of some of their individual leaders, as Arthur Compton. They all say one thing, as I do now from a different approach—science has now given man such stupendous power that the best knowledge, the best intentions, and the most drastic determination must be exerted if men are to live together rather than die together. Many of our law-makers and our leading military men, as General Marshall, see this equally clearly, but some do not. And the people as a whole are still thinking of the new atomic world as of Sunday supplement or Buck Rogers stories, far away and unreal. When England was down for the count of nine, and knew it, there was no quibbling on arrangements and details of sovereignty. Overnight the offer of joint citizenship in a joint nation was offered to France, which had taken the full count of ten. Could there be any hesitancy in forming a realistic world government if men really knew that they are now in greater peril than England was then?

Scientists and technologists are now presented with their supreme test and their supreme opportunity. Never before has mankind been so completely at the mercy of the material power unleashed by science, never before has it been so willing to accept the advice of the scientist in controlling and directing this power, to face and apply truth rather than wishfulness; never before has the technologist been under such a compulsion to hammer home to all, to hammer into deep-felt acceptance not surface word homage, the certainty which flows from his knowledge: that mankind will live in "One World—or none." Those of us responsible for instruments have become responsible for the future of man. We must not say, with Cain, "Am I my brother's keeper?"

TRAINING INSTRUMENT ENGINEERS

(Continued from Page 779)

familiar with those portions of all branches which directly affect him in his instrument work. The conventional engineering courses are not designed to train instrument engineers but rather to prepare competent specialists in the fields indicated by their names. Each covers far more territory in its specialty than the instrument engineer requires and does this at the expense of familiarity with other branches which the instrument engineer needs. A brief consideration of some of the applications of instrumentation in the rubber industry will serve to emphasize the extent and diversity of the field.

In the research and development laboratories where new products and processes come into being, one encounters the most important and varied application of instruments of all kinds. These include devices for weighing masses, determin-

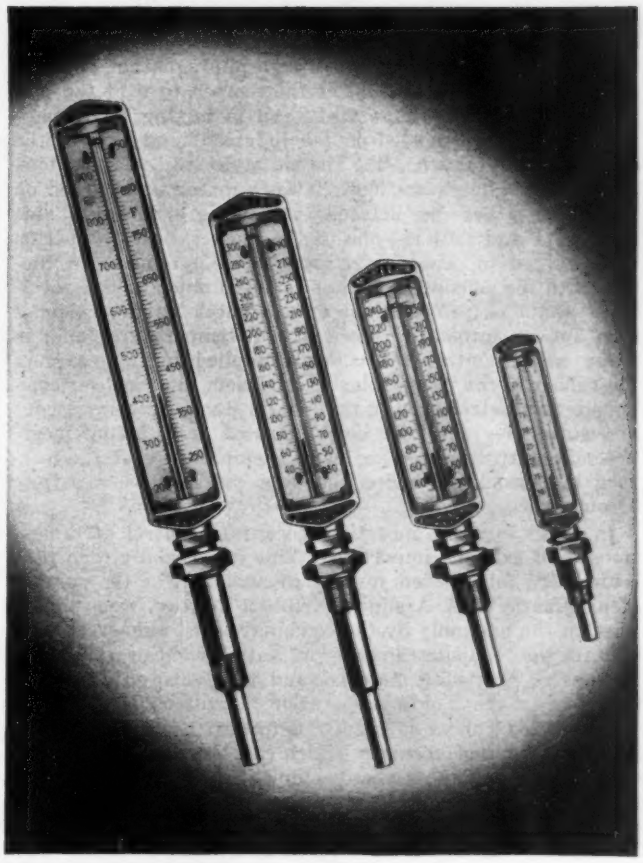
ing forces and pressures, measuring dimensions, metering flows, measuring and controlling time, temperatures and all sorts of physical, chemical and electrical properties of materials and products. Some are very specially constructed for particular purposes or for extreme precision. Others are of general application. They range from the delicate analytical balance capable of weighing a pencil mark to the huge testing machine which can rupture a bar of steel and from the cathode-ray oscillograph to the electron microscope. The scientists and engineers concerned with their design, application and use must be thoroughly familiar not only with how and why they work but also with what is happening in the article or process being tested. Without instruments there can be no tests—and it is only by such measurements that progress can be evaluated and that products and processes can be brought to the point where they are suitable for large-scale manufacture.

When commercial production is reached, the instrument problem changes. Accurate measurement is no less important than in the laboratory but control applied to repetitive or continuous operations—to assure the maintenance of the desired quality and quantity throughout large masses of production—becomes a most important objective. In the devising of such controls and in making them automatic so that personal variations are eliminated and accuracy and uniformity are improved, the instrument engineers of today have made outstanding contributions to industrial progress. These controls are just as diverse and cover as many fields of scientific knowledge as the methods of measurement used in the laboratory. In fact, the instrument problem is more involved because of the greater sturdiness required for constant use under factory conditions and because of the more complicated mechanization which is often involved. A few examples from the rubber industry may be of interest and may serve to emphasize the necessity for broad training of instrument engineers.

As most of you know, rubber compositions are compounded by the incorporation of various chemical ingredients to impart to them the properties which make them suitable for the use for which they are intended. The different characteristics of an inner tube, a tire tread or a battery jar are obtained by this means. The compounding is done according to a predetermined formula specifying the relative weights of the various materials employed which are assembled in proper proportions on a batch system prior to mixing. For large-scale production it frequently is necessary to prepare a great many of these batches consecutively, each one exactly like its predecessor. Formerly, the preparation of the batches and the proportioning of the ingredients was a manual operation carried on by a worker equipped with ordinary weighing scales. With the advent of the instrument engineer, automatic weighing-and-proportioning has been developed for many materials so that now through the use of hoppers, proportioning devices, automatically-controlled valves and automatic scales, the element of human error has been largely taken out of this fundamental process involved in preparation of all rubber compounds. The old method however, must still be employed where only a few batches of a particular mixture are required or where the physical nature of a material renders it unsuitable for this type of handling.

Since rubber compounds when in the processing stage must be warm and plastic and since their treatment with excess heat over a period of time causes the rubber compound to become vulcanized or elastic and in a form unsuitable for further working, proper control of temperature and plasticity is of great importance in rubber processing. By applying contact type pyrometers to the mixing mills and by devising instruments like the Mooney Plastometer and the Olsen Hardness Tester for measuring the actual plasticity and curing properties of the mixed rubber, the instrument engineer has taken much of the guesswork out of the rubber factory mill-rooms.

After mixing, the next step in processing rubber compounds frequently involves the shaping of the compounded and mixed material into sheets of definite thicknesses by means of calenders or into various other forms by extrud-



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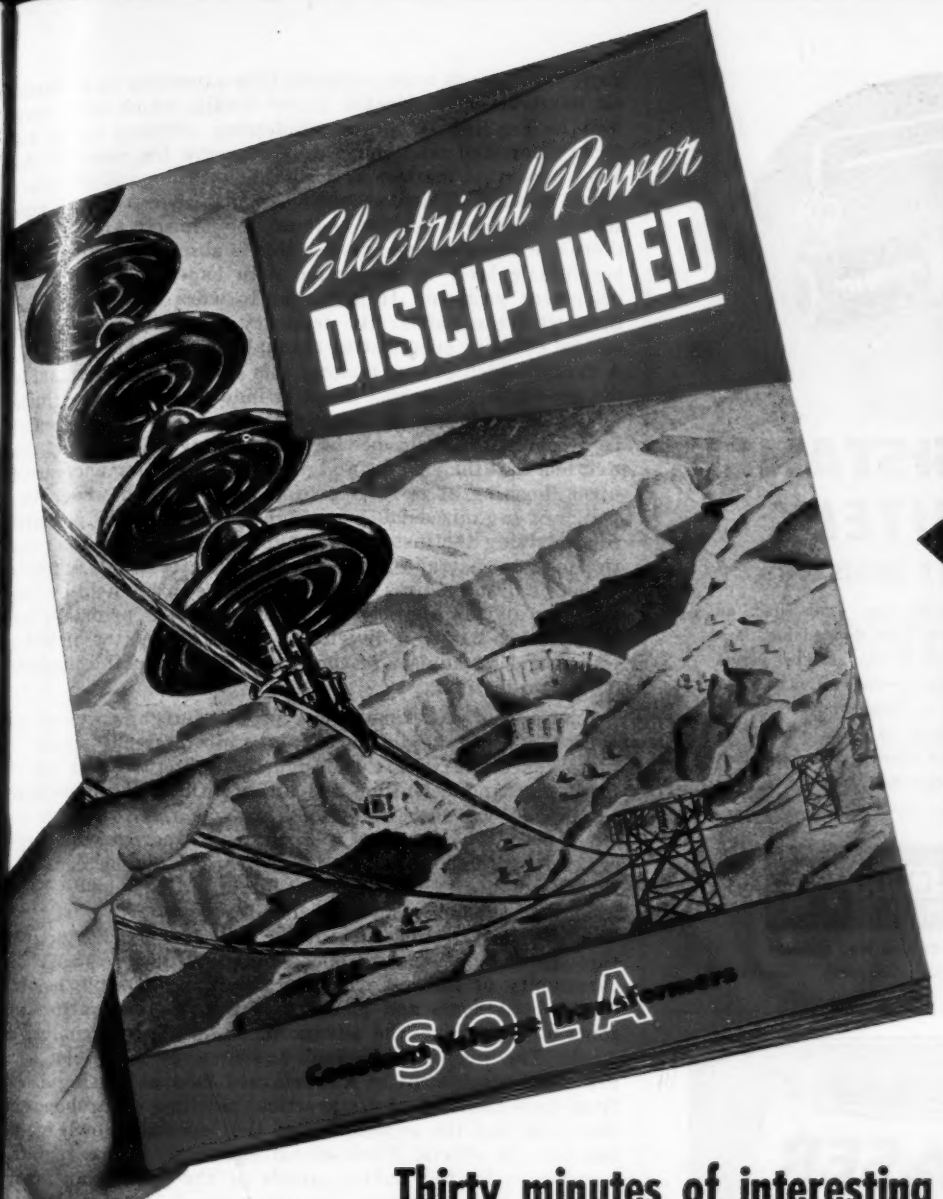
ing through dies. Calenders are also used for coating rubber on the surface of fabric or for actually forcing it into the interstices so as to give thorough impregnation. In these operations, accurate control of the temperature of the material is even more important than in mixing and, traditionally, it has depended on the judgment and skill of the calender operator who, like the old style steel heaters, took a look at the batch and how it was running and turned on more or less heat as dictated by his long experience. This man was—and still is—one of the most skilled production operators in the rubber factory; but a pyrometer in contact with the calender rolls has removed much of the guesswork and now provides not only a check on the calender man but an automatic record of roll temperatures and, in many cases, control of the heat supplied for maintaining the rubber in the proper plastic condition. Since rubber compounds themselves even in the plastic stage are very viscous and since they are poor conductors of heat, actual measurement during processing of the temperature of the mixture by automatic devices has not yet been successfully accomplished.

In these forming operations, accurate control of dimensions is of extreme importance. This is especially true with coated tire fabric used for the construction of the carcass of pneumatic tires. A slight variation in gage, when multiplied in the assembly by the combination of numerous plies to form the requisite thickness of wall, becomes serious both in causing waste of material and in creating subsequent difficulty in the molding operation. Unfortunately, plastic unvulcanized rubber is readily deformed by light pressure and the degree of accuracy which can be obtained by using the ordinary thickness micrometer or other pressure instruments is not adequate for these tire applications. Here again, instrument engineers have come to the rescue and have provided means for measurement and control which are used successfully to give the required accuracy and which do not depend on direct linear measurement of the thickness as is the case with mechanical micrometers. Two types of electrical measuring devices are employed and both can be arranged so as not only to measure and record continuously the thickness of long rolls of sheet material as it passes through the calender but also to automatically adjust the actual setting of the calender in case of excess variation so that the thickness is maintained within the permissible tolerances. One of these devices consists essentially of an electrical capacitor in a resonant circuit, between the metal plates of which the coated fabric passes as it leaves the calender. The rubber sheet serves as the dielectric in the capacitor and variations in its thickness change the capacitance. Variations thus produced in the circuit with proper electronic amplification operate an automatic recorder and can be used by suitable mechanization to actually operate motors and gears which will change the calender setting. The other common device consists essentially of a magnetic core carried on rollers which travel lightly on the rubber sheet as it passes over the calendar rolls. The core and the calender roll form a magnetic circuit. Primary and secondary coils are wound on the core. Variations in the rubber thickness change the air gap between the core and the roll, thereby varying the magnetic flux and the induced secondary current which operates a recorder. This device likewise is frequently used to control the setting of the calender.

After rubber compounds are processed and formed and the prepared materials are assembled for practically any rubber product, the most vital operation of vulcanization is carried out. It was here that some of the first and most important applications of automatic instrument control were made in the rubber industry. Vulcanization involves chemical reaction between rubber and sulphur and the rate at which this reaction progresses is critically dependent upon the temperature of the material during the reaction and the time during which that temperature is maintained. Ordinarily, the reaction does not take place at any appreciable rate at temperatures under about 240°F. unless special catalytic agents are used but, as the temperature is increased, the rate of reaction increases rapidly. It follows therefore that, by controlling the temperature and the time, the reaction can be started when desired, allowed to proceed to a given extent at a controlled rate and stopped at will. In this way, the proportion of sulphur which actually combines with the rubber in any given mixture can be controlled within close limits. Since the physical properties of the vulcanized product are closely related to the proportion of sulphur combined, such control of the reaction enables one to obtain with precision the final qualities desired in the product. Many difficulties encountered in the service rendered by rubber products in the past such as premature failure under stress, variations in hardness from piece to piece, premature cracking and embrittlement have been due to improper control of the vulcanizing conditions of time and temperature. Modern vulcanizing equipment is of many types, using various sources of heat, but it is nearly always provided with a variety of gages and controllers which regulate pressures, steam temperatures and vulcanizing time cycles. In the case of large valuable products like tires where the vulcanization process is complicated by the use of several heating and pressure media such as steam, water or air and where, because of the size and the poor conductivity of rubber, it is not possible to bring the entire mass to the same reaction temperature at the same time, very complex cycles of both time and temperature are necessary in order to obtain uniformity in the final product. An instrument engineer in designing and maintaining control equipment for such a purpose must indeed be a mechanical genius, an expert in the laws governing heat transfer and considerable of a chemical engineer in order that he may know what is happening in the process and may adapt his instrumentation to accomplish the desired results. Most recently, vulcanization is being accomplished by high-frequency induction heating and this is bringing an entire new set of instrument problems: now it appears that for this process alone the instrument engineer must have extensive knowledge of electrical engineering as well as the qualifications previously required.

Enough has been said concerning specific instrument applications in the rubber industry to show conclusively that an instrument engineer must have the broadest possible fundamental training to work successfully in that field. The usual college course cannot provide the fundamental tools which he will need in all of the fields, and at the same time give him the degree of specialization which is required for mastery in a particular one or in any single industry. The latter must come after he enters the industry through training on the job or through extension courses in the particular fields where his major interests lie. It has been found, with young engineers trained in mechanical or electrical engineering who later take positions in instrument departments in the rubber industry, that a valuable procedure is to start them in the testing laboratories where the work is not too unlike that done in engineering laboratories in college and where they receive instruction in the special technology of the industry and become familiar with many of the types and uses of instruments commonly employed. Too much emphasis, however, can hardly be placed on the importance of making certain during his training years that the instrument engineer is thoroughly grounded in the fundamental sciences and the basic principles of all engineering so that he may have the necessary foundation upon which he can later erect the superstructure of specialization as the need arises. If he is properly trained during his early period, a big step will have been taken toward assuring him suitable professional status in his maturity.

Instrument engineers have attained considerable recognition as professional specialists in the rubber industry as would be expected from their outstanding contribution to the advancement of its technology. There are those, however, who question whether the degree of recognition is commensurate with the importance of their contribution as evidenced both by the extent of their authority and their remuneration. If this is true, it can only be because these engineers have been so intent upon the technical aspects of their work that they have neglected to give sufficient attention to professional development. In many cases an instru-



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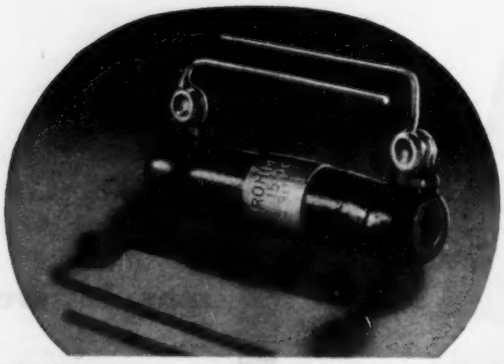

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ment man spends much valuable time attending to mechanical construction and other minor details which could very well be handled by skilled tradesmen working under his supervision and who could thus conserve his time for the more important matters of design, adaptation and organizational contacts. This does not mean that an instrument man should be above doing a manual job himself and, indeed, there are many occasions when this is absolutely indispensable—particularly in connection with experimental and development problems. It is harder to work with one's head than with the hands: the tendency to avoid concentrated mental effort by substituting manual work should be resisted. A factor which is now making this even more important is the growth of organized labor in industry and the attitude of the unions in insisting that certain types of manual effort be reserved for their members. Many engineers resent this and feel that their rights and privileges are being encroached upon. Looking at it from another viewpoint, however, this policy of organized labor might be regarded as a powerful force driving the instrument engineer away from the practice of a mere trade and into direct professional status in which he first acquires expert knowledge in his field by long training and apprenticeship and then serves primarily not as a worker but as a director of others, a creator of better things and an advisor of those who would use the products of his profession.

Last spring, here in the city of Pittsburgh, an event occurred of such significance to the professional status of those concerned with the design, manufacture and use of industrial and scientific instruments that its importance can hardly be overestimated. This was the formation on April 28 of The Instrument Society of America which was created by the unanimous decision of fifteen local or sectional societies to join together into a national body. These individual groups had undoubtedly come into existence through the years because of the inherent benefits derived through association with one another of those who have a community of interest. Such local activities, while helpful to the individuals and pleasant in the friendships formed, contribute little to the advancement of a profession as a whole. The word "profession" has come to imply not only professed attainment in a specialized field as distinguished from mere skill but also a practical handling of problems in that field and the application of that special knowledge to the uses of others. Professional status therefore requires recognition by the public outside of the particular group concerned and, in its most rigorous sense, is usually attained only when some assurance is available that satisfactory qualifications have been met (and in some cases only when some official authority or license is granted). Membership in a national technical society can and often does serve to assure the public that minimum qualifications have been established and attained as judged by those skilled in the specialized field. Without such an organization, it is difficult to see how those concerned with instrumentation could be properly considered as having professional status at all.

The nationwide movement in recent years for State registration and licensing of professional engineers is another important step toward full professional status. In most of the States, engineers can now obtain official certification, by a competent board legally created by the State, to the effect that they are qualified by training and experience to practice their profession. This is recognized by the courts and is accepted by all in authority as proof of professional status. Here again, as in the college courses, we find the field of engineering divided into traditional specialities and most of these groupings correspond closely to those followed by the colleges and by the technical societies. In no case do we have an official listing of the profession of instrument engineering. Today, an instrument engineer must be registered in one of the other branches such as chemical, electrical or mechanical engineering in order to use the title "Engineer" and to obtain the official recognition that he is a professional man at all. It would seem that a logical step for instrument engineers to take, now that they have their own technical society, would be to endeavor to have State registration boards for engineers recognize the instrument profession as

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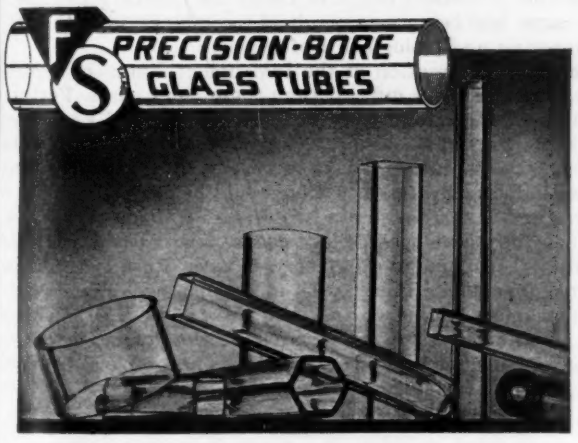

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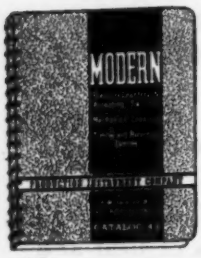

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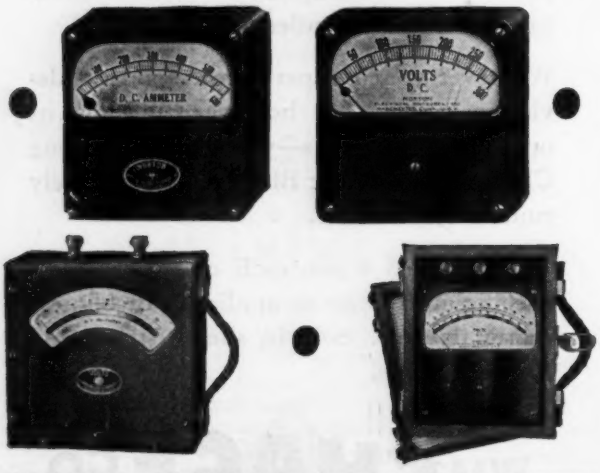

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a separate branch. A serious obstacle in such a program would seem to be that there is no school at present which likewise recognizes the profession of instrument engineering or that has set up a specific training program to prepare engineers for that profession. The suggestion is offered, therefore, that serious consideration be given to the establishment of such a course or at least to creating an officially recognized option in one of the existing engineering courses specifically pointing to the training of instrument engineers.

When one thinks of the present lack of a formal complete university course in instrument engineering he wonders why this situation continues to exist. The answer is undoubtedly found in the facts that industrial instrumentation is relatively new and that it is so complicated and involves so many different branches of knowledge that no one has really felt competent to make the necessary choices and plan the required courses of study. This same situation has existed heretofore in other cases. Some fifty years ago, another borderline field had no professional standing in its own right and yet graduates were being called upon to practice in this field in industry without proper formal training. Many schools gave courses in chemistry and even specialized instruction in so-called industrial chemistry. The same schools gave courses in mechanical engineering but the chemists knew little mechanical engineering and the mechanical engineers knew little chemistry. In industry, men were needed who knew considerable about both and when the demand became sufficiently evident, certain forward-looking institutions faced the problem. They reviewed their courses in chemistry and in mechanical engineering. They discarded what could be dispensed with from each, retaining the fundamental essentials of both which were then combined into a new course of training—and the Chemical Engineer came into being. He is neither a chemist nor a mechanical engineer but he is a well-trained engineer with a fundamental basic knowledge of chemistry which enables him to practice his profession throughout the whole enormous chemical industry.

Another precedent might be cited: the Sanitary Engineer, who came into being as a result of a combination of the civil engineering and biological professions.

Perhaps the creation of the Instrument Engineer profession is a little more difficult than these older cases. Perhaps it involves the combination of more branches of knowledge than has previously been attempted, which may make the choosing more difficult, but it seems certain that the demand exists industrially for men who would be trained in such a course and that its creation in the near future is inevitable. With a fully-developed college course leading to a scientific degree in Instrument Engineering, with State registration of instrument engineers, with a national technical society of instrument engineers and with the constantly increasing industrial demand for the services of men so qualified, there could be no doubt that the instrument engineer had attained full professional status in every respect and would receive the advantages and benefits pertaining thereto.

UNDERGRADUATE PREPARATION FOR THE FIELD OF INSTRUMENTATION

(Continued from Page 787)

tells me that one of his most instructive laboratory instruments is an ordinary U-tube manometer. This manometer had probably been broken and repaired at one time, for the two arms are of different diameters and a change in the measured pressure causes the mercury to rise more in one arm than it drops in the other. The student immediately observes this apparently strange phenomenon—and asks why. The student is then asked what makes him think the change in level should be the same in both columns. This results in considerable mental activity, all at the expense of collecting data—all for the good of the student's future career.

More attention must be paid to thought-provoking experiments. It does little good for a student to take data once he has learned to take data and record them accurate-

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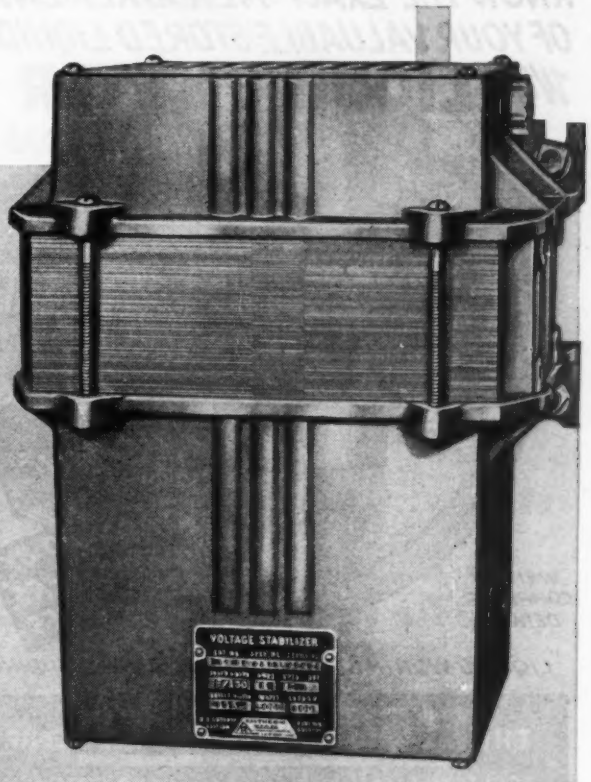

ENDBELL MODEL

TABLE 1—DIMENSIONS IN INCHES

Catalog Number	OVERALL			
	L		W	H
	50~	60~		
VR-5	13 1/8	12 1/2	9 5/8	8 1/2
VR-6	14 5/8	14	14 3/4	11 7/8
VR-7	17 1/2	16 3/8	14 3/4	11 7/8

CASED MODEL

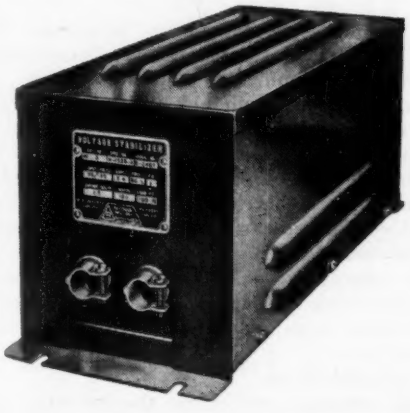

TABLE 2
DIMENSIONS IN INCHES

Catalog Number	OVERALL		
	L	W	H
VR-1	8 7/8	3 7/16	4 1/2
VR-2	11 3/8	5 7/8	5 5/8
VR-3	15	6	6 1/8
VR-4	18 5/8	7	8 7/8

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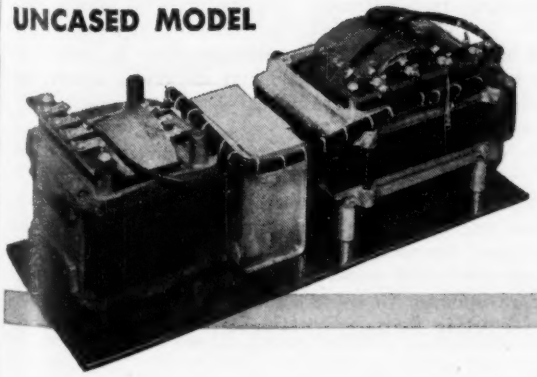

TABLE 3
DIMENSIONS IN INCHES

Catalog Number	OVERALL		
	L	W	H Max.
VR-1	7 9/16	3	3 5/8
VR-2	7 7/8	5 11/16	5 3/16
VR-3	12 7/32	5 11/16	5 3/8
VR-4	15 9/16	6 3/4	7

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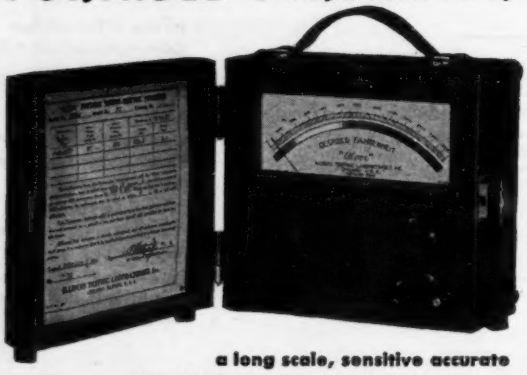

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ly, unless by so doing he can be made to learn something or to learn to think.

A class of students in electronics was once told that they were to study a certain phenomenon in the laboratory. The class was assigned the task of designing the experimental set-up for the following week's experiment (a very simple experiment). This was an excellent class of senior electrical engineers and physics majors and graduate students. Soon after the assignment was made, various solutions were presented. Everything was fine until the students were directed to specify the wattage ratings of the resistors involved, the ranges of the instruments to be used, etc. Most of the students had never thought about such things before. This turned out to be one of the most instructive experiences they had had. Up to that time many of them thought a laboratory was a place to take data. More thought along these lines in all the courses from English and Mathematics to shop work would result in turning out much better graduates. Too many courses are so set up that a student can think he is learning when he is only memorizing. If a student can be taught to think and reason, the content of a course is of secondary importance. If existing facilities are properly used an engineering student will have little difficulty in understanding industrial instruments.

Now let us discuss possible course work in measurement and control. It is out of the question to attempt to present a finished outline of a course, but it is possible to suggest some things worthy of consideration by anyone who proposes to teach such work.

The first question that arises is what type of engineers ought to take special work dealing with instrumentation. Perhaps the need is greatest for metallurgical and chemical engineers. We then have electrical, mechanical and aeronautical engineers to consider. The inclusion of these five groups rather broadens the scope of the work that must be included in a single course. Certainly metallurgical and chemical engineers ought to become familiar with the whole field, so it might be possible to outline a full year's work for these men. A course with emphasis on the measurement phases of Instrumentation might suffice for mechanical and electrical engineers whereas an additional treatment of servomechanisms could be of value to an aeronautical engineer.

The following subjects should receive attention in a general course on industrial instrumentation: Temperature, humidity, pressure, flow, liquid level, specific gravity, pH and gas analysis. The course should cover fundamental means of measuring these variables with a discussion of accuracy of measurement, lag and reproducibility of the primary measuring element. These same points should be discussed in considering industrial instruments for measuring these variables. The effects of lead lengths to instruments and ambient temperatures on instruments must not be forgotten. The laboratory could be reasonably complete if it included the following equipment: (controls are recommended so as to allow these same instruments to be used in studying control).

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3. Indicating millivoltmeter pyrometer with on-off control.
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5. Pressure indicator.
6. Differential-pressure flowmeter and area type flowmeter.
7. Pump and capacity and auxiliary equipment for flow.
8. Pneumatic controller with diaphragm valve for differential-pressure flowmeter.
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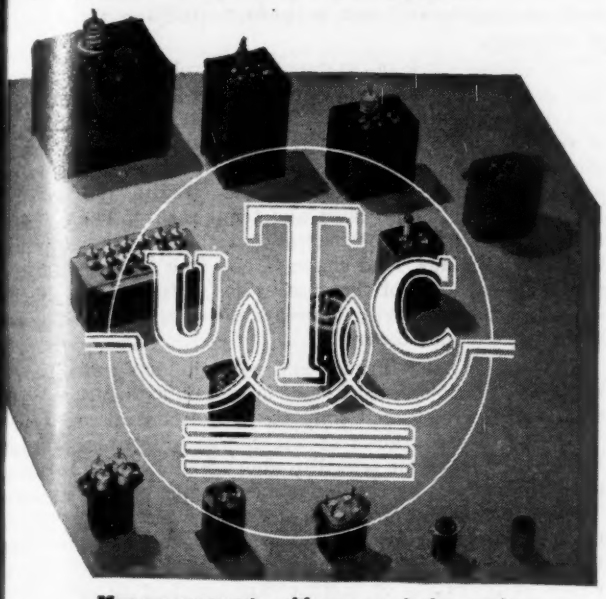

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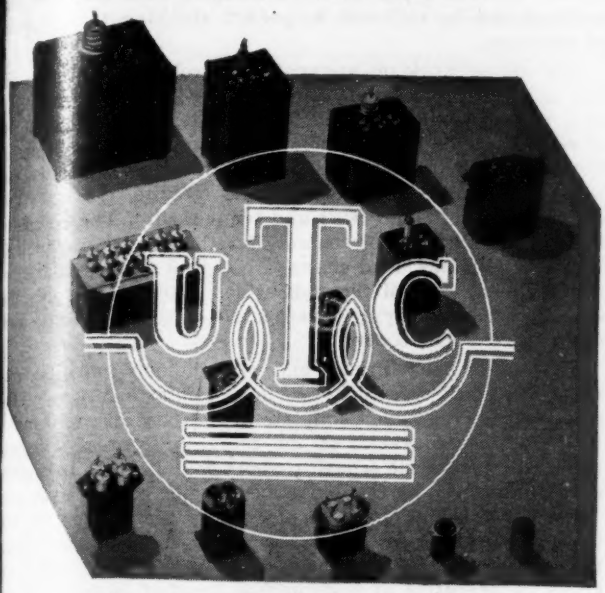

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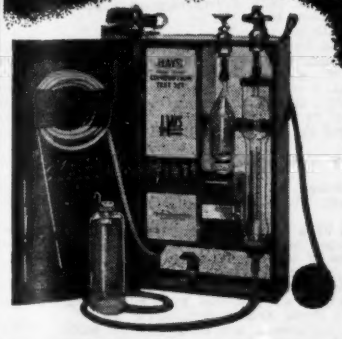

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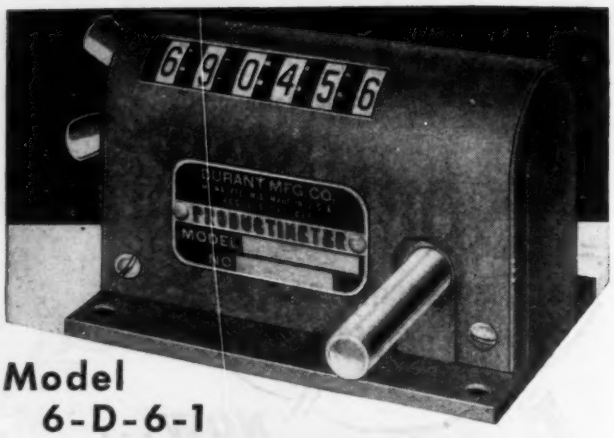

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11. Equipment for gas analysis and for the measurement of specific gravity, humidity, and pH would just about complete the list. The measurement of these variables however is not as common as measurement of the others mentioned. Several types of thermocouples with and without wells should be included to permit studying their speed of response.

The course work on automatic control should first cover the general problem of control. Servomechanisms might well be discussed from the fundamental mechanical point of view. It would be extremely helpful to correlate the equations and defined quantities in mechanical control problems with those associated with electric circuits and with the control of flow, liquid level and temperature. The complexities in certain types of control may then be studied including effects of lags, load changes, etc. One may then discuss the practical control methods which attempt to solve the existing problems, tying together all of the complexities of measurement and control.

With a gas-fired furnace and with the flow-control equipment mentioned above, it will be possible to set up conditions which pretty well simulate actual control problems.

The precise character of the course or courses will naturally vary from one school to another and will be to a large extent influenced by the department which offers the course. There are literally hundreds of types of control devices, but the general problem is the same for all of them. The fundamental variables to be measured and the fundamental principles of operation of instruments are few in spite of the almost infinite variety of instruments. If this fact is borne in mind in setting up new courses, the job will not appear so difficult.

I have carefully avoided the question "What department is best fitted to give a course in Instrumentation and Control?" As Dr. C. E. Mendenhall suggested 26 years ago, at the meeting of the American Institute of Metallurgical Engineers, such a discussion is likely to lead to a rise in temperatures too high to be measured by present methods. Certainly we have not developed means for their control. The person teaching such work should insofar as possible acquaint himself with these problems by studying processes in industrial plants. It would be a mistake to assume that the library can furnish all the background required.

Again let me emphasize the value of studying the present curriculum before adding new courses, and the necessity for close coöperation between departments. After all, the student ought to have the highest priority of anyone in the college, and courses should be devised for him, not for the department.

Statement of the Ownership, Management, Circulation, etc., Required by the Acts of Congress of August 24, 1912 and March 3, 1933 of *Instruments* published monthly at Pittsburgh, Pennsylvania, for October 1st, 1945.

State of Pennsylvania, County of Allegheny, (ss).

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Richard Rimbach, who, having been duly sworn according to law, deposes and says that he is the Publisher of *Instruments* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, to wit:

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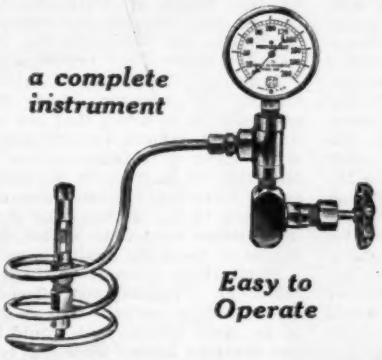

Easy to Operate

Determines the moisture content of the vapors of propane and other gases. Can also be used to determine the water concentration in liquid propane. Determines relative humidities over a comparatively wide range. Pressure gauge has a range of 0 to 200 pounds.

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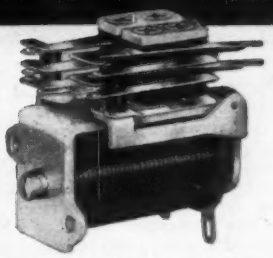
"AEROTROLS"



The Small Relays with the Big Performance

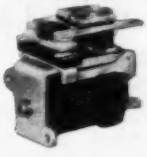
• Engineered and manufactured for the necessities of military aircraft operation, Cook "Aerotrols" have opened new fields in electrical and electronic remote control applications in radio-radar, wire communications, mining, manufacturing, testing and innumerable other fields where greater dependability and accuracy must be provided.

• Here are some of the general specifications of the "Aerotrol" "400" Series relays. The size of the "Aerotrol" without springs (the frame, coil and armature) is $^{15}/_{16}$" wide, $1^{7}/_{16}$" long and 1" high. Spring assemblies add to overall height, up to 1" for 6 springs. Average weight for two spring pile-ups is $1\frac{3}{4}$ oz. The coil spool is one piece, moulded bakelite. Heel piece is arranged for two mounting screws with solder terminal for coil located at the armature end, at which end also, spring solder terminals are located. Coil winding capacity can be provided up to 10,000 ohms and for positive operation on current values as low as 2 milliamperes. Coil treatment normally includes impregnation with fungus lacquer and Insulex covering, and where required, the coil is treated for high humidity and other tropical conditions.

• "Aerotrols" are small, compact, yet rigidly constructed relays that have proven their dependability, not only in laboratory tests, but in actual operation under the most severe wartime conditions all over the world.

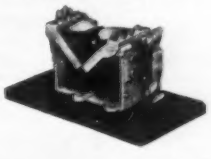
• "Aerotrols" are "application engineered" to provide specific performance suitable to circuit and control conditions. There are many selective features that can be incorporated into these relays. Bushings and insulators can be provided made of Cook patented "Cecotite" ceramics, to provide freedom from carbonization and wear, and to provide permanent stability of original adjustment and rapid frequency of operation. Mounting arrangements can be provided to meet installation conditions, including the plug-in types.

• "Aerotrols" of various types, such as time delay, latching, A.C. or D.C., both single and double pile-ups, can be supplied.



An "Aerotrol" heavy current relay with two form "A" contacts operating on a double armature.

Send for booklet AR-145 for full line of "Aerotrols."



Any combination of the "400" Series can be used in a latching "Aerotrol."

COOK ELECTRIC Company

CHICAGO 14, ILLINOIS

Instrument Societies

Instrument Society of America Holds Organization Meeting

FOLLOWING after the ISA-CIT Conference on Instrumentation and the University (which was attended by most delegates) the Instrument Society of America held an organization meeting at Pittsburgh on Friday, October 19th and Saturday, October 20th, attended by delegates, alternates, members and guests, from fourteen Societies (see tabulated attendance report).

The meeting was called to order by President *pro tem* Albert F. Sperry, who called upon each committee chairman to make a report on his committee activities to date, so that all delegates were given the opportunity to fully discuss the various details presented. Much time was devoted to certain articles in the proposed Constitution, the amount and method of collection of dues, publications being planned, the scheduled "Exhibit" next year, and other matters of general interest.

Constitution Takes Shape

Constitution Committee Chairman M. H. White (Philadelphia) reported at the Friday meeting that the major comments seemed to be regarding classification of membership, and method of election of officers. A lengthy discussion then ensued on those two points during both days. Some delegates favored only one full-member grade, others recommended a lower-grade member who would pay less dues, in addition to the Junior or Student grade. When voting on these matters on Saturday, the majority of the delegates agreed on four grades: Honorary Member, Member, Associate Member, and Student Member.

Then the question was put relative to election of officers, attention being directed to the difficulty of electing, by letter ballot, men who were best able and willing to serve. When voted on, the majority of the delegates approved election of officers by the Board of Directors; the Nominating Committee to furnish a list of nominees as obtained from the Sections.

After the Constitution had been rewritten to incorporate these changes, each article was separately voted on, and the complete Constitution was unanimously approved by the delegates in the form as rewritten. The Constitution Committee put in a lot of concentrated effort, and their final draft was completed in the early morning hours. The Executive Secretary will now send copies of this approved Constitution to all Sections for ratification.

The Constitution Committee will now start work on compiling the By-Laws, and copies of same will later be sent to the Sections also, but it is not considered that such By-Laws will require ratification by the Sections.

Exhibit Now Definitely Scheduled

Exhibit Committee Chairman Paul G. Exline (Pittsburgh) advised that the "Exhibit and Conference" is to be held September 16th to 20th, 1946, in Pittsburgh. He reported that 130 exhibit booths will be available, according to present plans, although more may be added if necessary; and that 62 manufacturers had already reserved 92 of those booths. He proposed that the theme of the Instrumentation Exhibit might be "Future Types and Uses of Instruments." He called attention to the large amount of work that will be necessary to make the Exhibit a real success, and proposed that various sub-committees be organized to take care of the over-all planning, program, publicity, also liaison with the technical societies and manufacturers. The majority of the delegates agreed that all such committees should be appointed from the Pittsburgh Section so that all work together to best advantage.

Society Needs Money

Finance Committee Chairman H. E. Ferguson (Chicago) called attention to the questions of dues, "sustaining" membership, manufacturer contributions, and other forms of income that must be settled before any budget can be planned. Several of the delegates then offered ideas as to the amounts of dues for the different grades of membership, also the proportionate share to go to the Sections. When voted on, unanimous approval was given the following schedule of annual dues:

Member—$10.00.
Associate Member—$5.00.
Student Member—$2.00.

It was also agreed that bills for dues be sent out by the Executive Secretary who would send out receipts, and then he would transmit 50% of the dues to the Sections. Much discussion then ensued regarding "sustaining" membership and/or contributions from manufacturers, and it was finally agreed to let this be tabled for the present. Attention was called to the financial condition of the Society, and that some money would be needed to keep going before the 1946 dues could be collected. After discussion, it was decided to ask each Section Treasurer to contribute as soon as possible an amount equivalent to $1.00 per member, such amount to be considered as an advance payment on 1946 dues. The Secretary *pro tem* stated that the billing work would be much reduced if it could be spread over the entire year, instead of mailing out all bills at one time. Collection of 1946 dues was left open for later discussion.

Membership Increasing

Membership Committee Chairman C. O. Fairchild (New York) reminded the delegates that the ultimate success of the Society will be largely due to the cooperation extended by each and every member, and our present membership will have to be doubled or tripled in order to have a Society with a satisfactory financial status. It was announced that the Society now has 1411 members in 18 Sections who have joined, that St. Louis is now in the Society, and two new sections have been formed, at Kalamazoo and Muscle Shoals. Attention was directed to the new membership brochure that was issued during the past summer, which has since been widely distributed, many copies going to men who have written for information. It was suggested that the membership chairman of each Section should keep in close touch with Dr. Fairchild, so that he can work with them and have the benefit of ideas that will promote interest in the Society, also help him in the selection of cities where new Sections should be organized.

The make-up and form of a proposed application form was discussed, and attention directed to the space provided for the applicant to indicate the grade of membership desired, also space for the Section to approve such membership grade; the idea being that the application form would be sent to the Section for approval of grade of membership only.

Other Committees Active

Nominating Committee Chairman R. D. Webb (Charleston) stated that he had not been able to make much progress, as he had been forced to wait until the decision had been made as to how the officers were to be elected. Now that election is to be made by the Board of Directors, he plans to contact each Section for suggestions as to candidates for offices in the Society, and will appreciate their recommendations.

Program Committee Chairman R. C. Darnell (Washington) spoke of the different types of program that can be arranged, scientific, technical, manufacturers, also the establishing of training courses with the cooperation of instrument manufacturers. He called attention to the assistance that can be given to the Sections, by distribution of information regarding topics for meetings, names of speakers, available movies, etc.

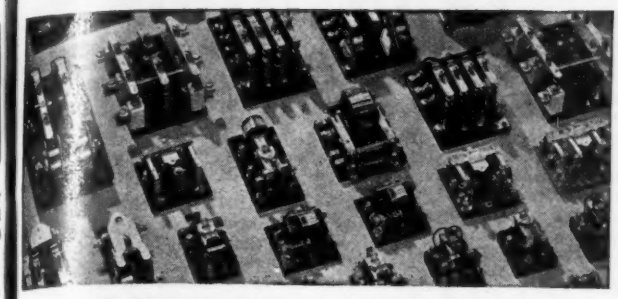
Publication Committee Chairman W. A. Wildhack (Washington) offered some good ideas as to a bulletin that might be issued in the near future, that would help to keep the Sections better informed regarding the Society doings, but it was decided to postpone action on this until the Society's financial condition improves. Bill Wildhack asked that the Sections keep him advised as to the types of booklets, or kinds of publications, that would be desirable to develop, also whether there should be an attempt to include advertising to help defray the costs.

Subcommittee Chairman Philip Ewald (Muscle Shoals) submitted various designs for an insignia that could be made up for a Society pin, also for use on stationery. Decision could not be reached; the matter was therefore referred back to the Committee.

Employment Committee Chairman Rimbach reported progress and told of the various correspondence that he had been having with those seeking employment, and also with companies having vacancies. He reported that two members had recently secured employment through the efforts of his committee. He called attention to the fact that his employment facilities are open

ATTENDANCE AT PITTSBURGH MEETING OF THE I.S.A.
Roosevelt Hotel, October 19th and 20th, 1945

Section	*Delegate*	*Alternate*	*Guests*
Chicago	Wm. E. Mahaffay	H. E. Ferguson	A. L. Sperry, R. R. Procter, Earl C. Rieger, D. Dickey.
Charleston	R. D. Webb		J. Steven, C. Holz.
Detroit	H. H. Barnum		
Indianapolis	Morris Underwood		
Kalamazoo	Wade Allen		
Muscle Shoals	Philip Ewald		
New Jersey	R. F. Roberts		
New York	C. O. Fairchild	C. Kayan	
Northern Indiana	E. Bainbridge		
Philadelphia	M. H. White	J. Johnston	
Pittsburgh	A. E. Shafer	R. J. S. Pigott	P. G. Exline, W. R. Gray, M. F. Behar, R. Rimbach, L. M. Susany.
St. Louis	R. H. Munch		
Washington	W. A. Wildhack	R. C. Darnell	
Wyandotte	W. G. Baker		



BULLETINS TELL THE WHOLE RELAY STORY

Bulletin 105—"Little Giant Relay" single pole, single and double throw. Controls ¾ HP on 115-230V.

Bulletin 106—Midget Relays for light duty available in single and double pole, single and double throw.

Bulletin 81—Intermediate Duty Relays in single and multipole arrangements, single and double throw.

Bulletin 362—Motor Driven Time Delay Relays for operation on alternating current.

Bulletin 104—Midget Relay for tight places—Vibration resistant—Double Pole, Double Throw—Available for 6 to 115 volts A.C. or D.C.

Bulletin 131 and 132—Heavy Duty Relays single and multipole, single and double, contacts rated up to 25 amp. on 125-250V.

Bulletin 251—Sensitive Type Relays for direct and alternating current operating on .014 watts.

Bulletin 351—Thermal Time Delay Relays with thermostat built into relay assembly.

Bulletin 103—Aircraft Power Relay. Single Pole, Single Throw for 24 volts at 25 amps. D.C. Withstands high values of acceleration of gravity, shock, and vibration.

WARD LEONARD RELAYS include types and sizes for every application. They all have crisp action, are dependable and durable yet consume but little current. Send for the data bulletins of interest to you.

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Electric control devices since 1892

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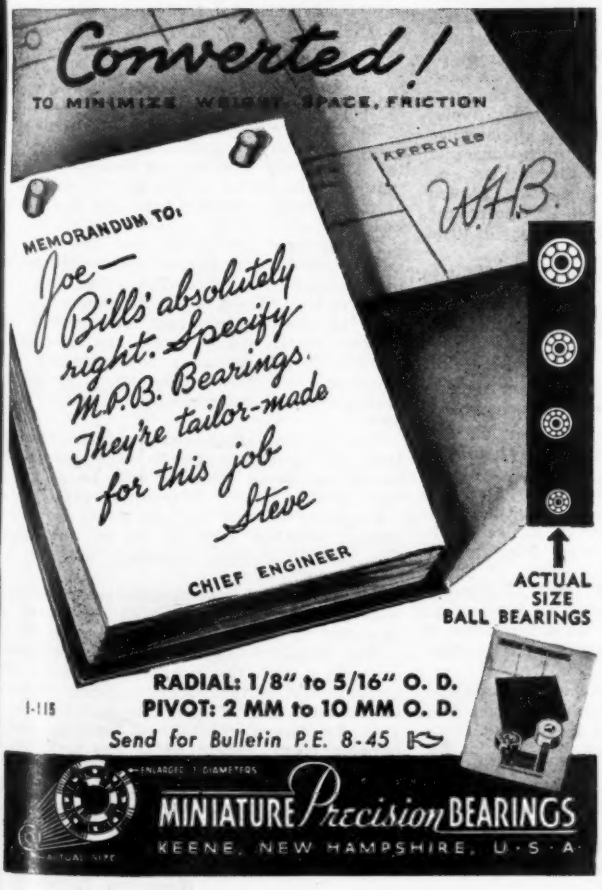

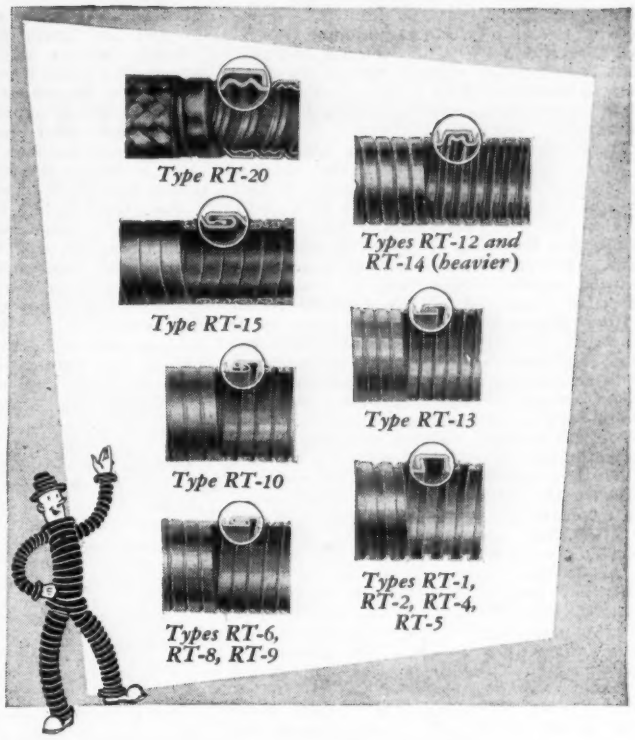

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Production men throughout industry know that many of their exacting problems can be solved with Rex-Tube or with the other flexible metal hose products in the complete C.M.H. line, including: Rex-Weld, Rex-Flex S.S., Avioflex and Cellulined. We know we can help you, too! Write today for Booklet E-144.

Flexible Metal Hose for Every Industrial Use

CHICAGO METAL HOSE CORPORATION

MAYWOOD, ILLINOIS

Plants: Maywood and Elgin, Ill.

to all, and not necessarily limited to members of the Society. He is planning to send out a questionnaire to all Sections, and asks that each Section appoint one of its members to coöperate with him so that employment opportunities will be available in all parts of the country.

DELEGATES ENJOYED SOCIABLE EVENING

Upon adjournment of the Friday session, all members and guests enjoyed a get-together cocktail party, followed by a group dinner in the Presidential Suite of the hotel, that had been reserved for our meetings. After dinner, a humorous movie was shown, entitled "How Not to Conduct a Meeting"; and then an exceedingly illuminating illustrated presentation was made by R. R. Proctor on the subject: "Distribution, Diffusion and Transfer Coefficients," which was not so dry and theoretical as some outsiders might imagine, but was most entertaining in its originality. It was after this sociable evening that the Constitution Committee took themselves off to a quiet (?) corner, where they proceeded to prepare the final draft of the Constitution, to reconcile all of the ideas expressed during the day's sessions. And they continued working until the early morning hours.

After the formal adjournment of the Saturday sessions, another dinner was arranged, with Pro-tem Vice-President Carl Kayan presiding. At the end of the dinner, the conversation turned to the question as to where shall we meet again, whereupon an invitation was extended by H. H. Barnum (Detroit) that the next Society meeting be held at Detroit. A motion was made and unanimously carried, that we should meet next at Detroit early in the Spring of 1946, the date to be later settled.

Although many delegates drifted away on Saturday evening, some of them remained for breakfast on Sunday, also congregated in various hotel rooms for more discussion, until their departure by train, by plane, or by automobile.

—RICHARD F. ROBERTS,
Chairman Publicity Committee

CHARLESTON, W. VA.

"Flow Measurement and Kindred Subjects" was the subject of an address given by H. V. Beck of the American Meter Company at the October meeting of the Charleston, W. Va., Section, I.S.A.

Mr. Beck discussed the basic principles of flow measurement and the various factors to be considered in designing a flow measurement installation. He pointed out the advantages and disadvantages of flow nozzles vs. the flat plate orifice and discussed the use of orifice flanges.

An interesting discussion period followed Mr. Beck's talk and many pertinent questions were answered.

—M. B. LORIG, *Secretary*

FORT WORTH

The Fort Worth Electronics Club resumed its regular monthly meetings on September 20, after a two-month recess.

Ray Basham of Consolidated Vultee Corp. presented a program on "Recently Released Electronic Devices" used by the Aircraft Industry, at this meeting.

H. F. Spreen of the Texas Electric Service Company conducted the program for the October 18th meeting, his subject being "Electrostatic Detearing."

We are looking forward for many interesting meetings this year. It would be a pleasure to the members if you should find the opportunity to visit Texas.

W. H. FARRINGTON, *Sec.-Treas.*

KANSAS CITY

At the October 30th meeting of the Kansas City Industrial Instrumentation Society, R. J. Hunter of Standard Oil Co. presented the names selected by the Nomination Committee, as follows: For President—Wm. G. Eargle, Phillips Petroleum Co. and Lester Johnson, Sinclair Refining Co. For Vice-President—John Marsh of Corn Products Refining Co. and Robert Cook of Westinghouse Electric Corp. For Secretary-Treasurer—Oliver Boutros of Boutros Instrument Co. and Lee Lewis of Economy Equip. Co.

Baker Manley of J. F. Pritchard Co. presented a basic lecture on "Control Valve Sizing for Reciprocating Pumps." Baker did a fine job in explaining how this should be done and went one step further by presenting each member with a mimeographed sheet including the necessary formulae and tables, for ready future reference.

Our "Quiz Kids," Roy Carns of Sinclair Refining Co., Lee Lewis of Economy Equipment Company, and Bob Spengler of H. O. Trerice Co., handled all the questions with the exception of two. We'll throw one of the questions open to all of you reading this, and that is "What is the maximum temperature and pressure rating for which 12″ to 24″ automatic control valves have been designed." We would appreciate someone helping our "Quiz Kids" on this.

Our guest speaker, L. K. Spink of Foxboro Co., presented a splendid illustrated talk on "Flow-measurement Engineering." He had all the answers! The members obtained a world of information on the installation and maintenance of flow devices. Mr. Spink presented each member with a copy of his "Characteristics of Differential Flow Meters and Factors Affecting Their Operation." All the members enjoyed this meeting immensely and we thank Mr. Spink and Foxboro Co. for making it possible.

—W. A. REICHOW, *President*

NEW JERSEY

The 1945 fall season of the Society for Measurement and Control opened on October 2, 1945, at the Essex House, Newark. The meeting was attended by 60 members and 42 guests.

During the introductory portion of the meeting, Vice-president W. C. Ludi outlined the proposed program for the 1945-46 season. It seemed obvious that we have an excellent outlook in prospect.

Our speaker, E. R. Huckman of Foxboro's New York office, presented an interesting chalk talk on air-operated control. He developed his thoughts by considering each of the four basic types, on-off, proportional, proportional plus floating and derivative. Mr. Huckman's approach was unique and he encouraged discussion by calling for questions at the end of his remarks on each type of control. The questions were thought-provoking and the discussions were lively.

Mr. Huckman emphasized the importance of each type of control, its limitations and applications. During the discussions, he drew on his fund of information gained through experience, stressed especially the applications and answered most of the questions with examples.

His talk went to prove that even though we are dealing with an exact science, experience is still the best teacher.

—H. S. CLOSE, *Secretary*

NORTHERN INDIANA SOCIETY FOR MEASUREMENT AND CONTROL

EDUCATION—FRATERNITY—DEMOCRACY

The Northern Indiana Section of the Instrument Society of America held its October meeting on the evening of October 19, at the Lake Hotel in Gary, Ind.

Following the dinner the meeting was turned over to C. B. Moore of Moore Products Co., Philadelphia, who presented a talk on the Null Balance method of pneumatic control. The talk was illustrated with colored slides and was so interesting and well presented one could have heard the well-known pin drop at any time during the address.

He cautioned against comparing pneumatic null balance to electrical null balance, and his slide clearly depicting all control functions in one graph, went over in a big way. His down-to-earth definition and explanation of derivative control gave many of us a clearer picture of that control function.

The substance of this talk may be found in an article by Mr. Moore in the September issue of *Instruments*.

Mr. Moore proved to be an entertainer as well as an educator when he spiced his talk with humorous incidents and stories drawn from his experience in the field of Instrumentation.

The meeting adjourned with all members agreeing they had spent the evening most profitably.

—EDWARD WHITE,
Publicity Chairman

WASHINGTON

The October meeting of the Instrument Society of Washington, held October 16 in the Interior Department Auditorium, was addressed by Mr. Gordon Rosholt, Engineer of the Aeronautical Division of the Minneapolis-Honeywell Regulator Co.

The speaker described and exhibited a number of electronic controls and instruments recently developed by his company. The working models were made available for inspection and operation by the audience following a question period.

It was announced that at least six representatives of various Government agencies would attend the Conference on Instrumentation and the University at Pittsburgh.

—W. A. WILDHACK,
Corresponding Secretary

WYANDOTTE

At the October 22 meeting of the Instrument Society of Wayne County, the illustrated lecture on telemetering by Perry Borden of the Bristol Co. was very instructive and very much appreciated. We were greatly interested in the ingenuity and variety of the devices used. Few of us knew that telemetering devices were in use eighty years ago.

We are glad the I.S.A. meeting will be held in Detroit next spring, and several of us will attend its sessions.

—JOHN MACPHERSON, *Vice President*

THE AUSTRALIAN SOCIETY OF INSTRUMENT TECHNOLOGY

2nd October, 1945.

Exhibition of Industrial Instruments
Melbourne, Australia, 1947.

The Australian Society of Instrument Technology is taking steps to organise a public Exhibition of Industrial Instruments in Melbourne early in 1947. The date has been put well ahead to enable exhibitors to make suitable arrangements, and also to enable the fullest scope for the display of post-war designs.

The Society is a non-partisan body and the purpose of the Exhibition is to improve the knowledge and use of instruments in industry and to be of interest to members of the Society, industrialists and the public generally.

The Society intends to seek the help of manufacturers, importers and retailers of instruments on the broadest basis, and any firms willing to assist, or interested to take part in the organisation are invited to register their names with the Honorary Secretary. No financial commitments are involved in thus registering. Overseas manufacturers are specially invited to take part.

The general arrangement of the Exhibition will probably be to rent stands to exhibiting firms. Stands will be supplied with electric power (230-volt 50-cycle a.c.), compressed air and running water, so as to enable working exhibits to be displayed. The Exhibition will probably last one or two weeks.

An illustrated and descriptive catalogue will be published, and the Exhibition is expected to be a good advertising medium.

The Society's activities are principally concerned with the use of measuring, recording and automatic controlling devices in industry, and it is not intended to provide for the Exhibition of general engineering plant, except as it has a bearing on instruments.

Further information will be published from time to time as it becomes available. The address of the Society is 93 William Street, Melbourne, Australia.

—P. A. CRIVELLI,
Honorary Secretary

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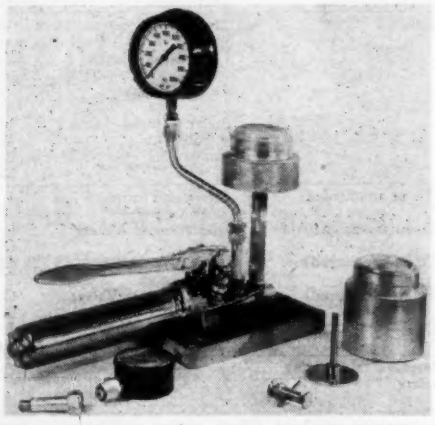
hydrostatic TEST UNIT

Guaranteed to hold pressures to 10,000 psi without leakage or seepage . . . even with grit!



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(also Portable Field Unit)

A dependable, precision unit for testing and repairing pressure gages and instruments . . setting hydraulic valves, relief valves, etc. . . . hydrostatic testing. Standard sets of dead weights range from 5 to 1,000 psi to 5 to 10,000 psi. Equipped with Twin Seal chack valve.

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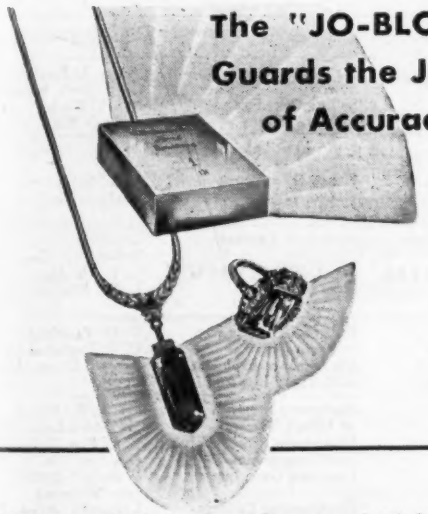

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Right now, with the long-hoped-for post-war battle for business getting into full swing, the establishment of high standards of shop accuracy becomes all-important in thousands of plants.

Don't let the hurry of reconversion sidetrack this basic precaution. Protect the performance of your product—make assembly easier—provide parts interchangeability—with genuine Ford Johansson Gage Blocks.

Guaranteed accurate within .000002, .000004 or .000008 of an inch, plus or minus. Available in sets or individual blocks, with all accessories needed to establish and maintain true accuracy in your plant. Write for new Catalog.

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IF YOUR RELAY REQUIREMENTS ARE:

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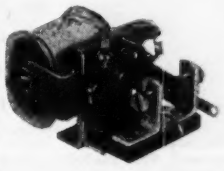
TYPE 4F

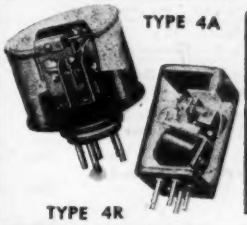


4F

This is the Series 4 relay with open frame construction. It is compact (1⅝" x 1⅜" x 1-5/32"), fast (2 - - 3 milliseconds with sufficient power), sensitive (.010 watts minimum).

★

TYPE 4A



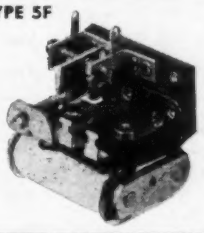
TYPE 4R

TYPES 4A AND 4R

These are the basic Series 4 construction with enclosures. The 4A is 2⅛" diameter and 2⅛" high, the 4R ½" x 1½" x 2⅝". Both have a 5-pin plug in base. The 4A can be sealed (4AH).

★

TYPE 5F

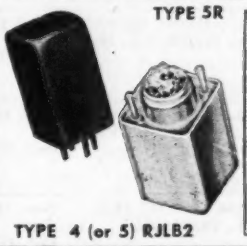


5F

This is the Series 5 relay with open frame construction. It is exceedingly sensitive (.0005 watts minimum), very rugged, precise in operation even under extremes of temperature and vibration.

★

TYPE 5R



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TYPES 5R AND 4 (or 5) RJLB2

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INSTRUMENT SOCIETIES CALENDAR

City, Society and Secretary			Date	Place	Subject	Speaker
Atlanta, Georgia	Georgia Society for Measurement & Control	Robert E. Geminert, P.O. Box 1714, Atlanta		Blue Flame Room, Atlanta Gas Light Co.		
Baltimore, Maryland	Baltimore Industrial Instrumentation Society	F. Ragan, Fuel Div., Beth Steel, Sparrows Pt., Md.	Nov. 29(C)	Engineers Club, 6 W. Fayette St., Balto.	Liquid in Glass Thermometer	W. D. Laverell, Precision Therm. & Inst. Co.
Charleston, W. Va.	Charleston Instrument Society	M. B. Lorig, 1506 Virginia St., Charleston 1	Nov. 12	Kanawha Hotel	Electronic Potentiometers	W P Wills
			Dec. 3(A)		(Annual Business Meeting)	
			Jan. 7(A)		Combustion Control	T. A. Cohen, Wheelco Co.
			Feb. 4(A)		Telemetering	P. A. Borden, Bristol Co.
			Mar. 4(A)		Boiler Control	M. J. Boho, Hagan Corp.
			Apr. 1(A)		Control Valves	Bruce A. Irwin, Mason-Neilan Co.
Chicago, Illinois	Chicago Section, I. S. A.	A. J. Butler, c/o IHC, 2626 W. 31st Blvd., Chicago	Dec. 3(B)	(To be announced)	Strain and torque meas. in aircraft	L. S. Wasserman, AAC, Wright Field
			Jan. 7(B)	(To be announced)	Displacement Meters	E. W. Jacobson, Gulf Research
			Feb. 4(B)	(To be announced)	Instrumentation in Plant Design	(To be announced)
			Mar. 4(B)	(To be announced)	Application of Valves in Automatic Control	C. E. Mason, Bristol Co.
			Apr. 1(B)	(To be announced)	New Optical Tools	J. W. Forrest, Bausch & Lomb
Cleveland, Ohio	Cleveland Instrumentation Society	A. J. McCullough, Minneapolis-Honeywell, 1001 Euclid Ave., Cleveland 3		Cleveland Engineering Society		
Detroit, Mich.	Instrument Society of Detroit	Cliff Sackett, Chrysler Eng'g 12800 Oakland Ave. Det't				
Florence, Alabama	Muscle Shoals Instrument Society	J. W. Moffett, 323 E. Mobile St., Florence				
Fort Worth, Texas	Fort Worth Electronics Club	Ralph Ely, 1116 E. Arlington, Fort Worth		Texas Hotel, Fort Worth		
Gulf Coast (Texas)	Gulf Coast Section, I. S. A.	C. D. Hoke, 2909 Lake Shore Dr., Port Arthur, Texas				
Hartford, Conn.	Hartford Society for Measurement & Control	Gustave L. Manke, c/o Veeder-Root, Sargent & Garden Sts.	Nov. 20(B)	Bond Hotel	ASA Standards	E. J. Bryant, Greenfield Tap & Die
			Dec. 18(B)	Bond Hotel	Testing Elec. Inst's	Fred W. Lingel, Triplex Elec. Inst. Co.
			Jan. 22(B)	Bond Hotel	Practical Inspection of Metals	Dave Nemser, International Nickel Co.
			Feb. 19(B)	Bond Hotel	Use of Air in Gaging	R. Y. Moss, Sheffield Corp.
			Mar. 19(B)	Bond Hotel	Electron Microscope	Dr. R. B. Barnes, G. J. Burton, Amer. Cyanamid
			Apr. 16(B)	Bond Hotel	Comparison of Materials for Gages	H. O. Richter, W. R. Moore, Norton Co.
Kansas City, Missouri	KC Industrial Instrumentation Society	Gordon H. Burke, 1527 Broadway, Kansas City, Mo.		Bluebird Cafeteria		
Los Angeles, Calif.	California Instrument Society	M. D. Pugh, 541 South Spring St., Los Angeles, Calif.		Melody Lane, Los Angeles		
Newark, N. J.	Society for Measurement & Control (New Jersey)	H. S. Close, 831 Dixie Lane, Plainfield, N. J.	Nov. 15(B)	Essex House	Instrumentation in Industrial Power Plant	Julius J. Berger, Cons. Engr. Newark
			Dec. 4(B)	Essex House	Selling Inst. Dept. to Management	M. H. White, Atlantic Ref. Co.
New York, N. Y.	New York Society for Measurement & Control	H. L. Hildenbrand, 206-07 33d Ave., Bayside, L.I., N.Y.	Nov. 15(B)	Essex House, Newark, N. J.	(Joint meeting with N. J. Soc.—see above)	
			Nov. 26(B)	Columbia U. Men's Faculty Club, 400 W. 117th St.	Flow Measurement	L. K. Spink, Foxboro Co.
N. Indiana	Northern Indiana Section, I. S. A.	C. P. Haynes, Red River Oil Refinery, 935 — 177th Place, Hammond, Ind.	Nov. 16(C)	Lake Hotel, 740 Washington St., Gary	Pneumatic Control	Earl Bush, Brown Inst. Co.
			Dec. 14(C)	Ultra Modern Dining Rm. Indianapolis Blvd., E. Chicago, Ill.	What, Where, Why & How of Draft	C. B. Hovland, L. W. Murphy Co.
Philadelphia, Pa.	Philadelphia Society for Instrumentation	G. E. Gress, c/o ATC, 34 E. Logan St., Philadelphia	Nov. 21(B)	Broadwood Hotel, Broad & Wood Sts.	Role of Galvanometer in Recorders	C. O. Fairchild, C. J. Tagliabue Co.
			Dec. 19(B)	Broadwood Hotel, Broad & Wood Sts.	Maintenance Problems in Refinery Inst'tion	Edward Grace, Albert Krieg
Pittsburgh, Pa.	Pittsburgh Section, I.S.A.	L. M. Sunny, c/o Carnegie Institute, 4400 Forbes St.	Nov. 26(B)	Roosevelt Hotel	Electronic Methods of Metals Testing	Dr. E. R. Mann, Du Mont Labs.
			Dec. 17(B)	Roosevelt Hotel	Diaphragm Motor Valves and Components	L. E. Eige, Fisher Governor Co.
			Jan. 28(B)	Roosevelt Hotel	Captured Gyro Inst's	Walter T. Buhl, Jack & Heintz
			Feb. 25(B)	Roosevelt Hotel	Fractionating Column Control	Lyman H. Allen, Jr. Amer. Viscose Corp.
			Mar. 25(B)	Roosevelt Hotel	Inst. Maintenance in Oil Refinery	M. H. White, Atlantic Ref. Co.
			Apr. 22(B)	Roosevelt Hotel	Control Valve Characteristics	R. Rockwell, Mason-Neilan Co.
St. Louis, Mo.	St. Louis Society for Instrumentation	Gus Holubeck, Union Electric Co., Venice, Ill.		DeSoto Hotel, 11th & Locust Sts.		
Kingsport, Tenn.	Tennessee Section, I. S. A.	C. F. Palmer, 2924 J. C. Hwy., Kingsport		Kingsport Inn		
Toronto, Ontario	Canadian Society for Measurement & Control	T. C. Agnew, Minneapolis-Honeywell Reg. Co.	Nov. 15(B)	Chez Paree Restaurant, 220 Bloor St., W.	Contributions of Research to Progress	G. E. Bourne, Canadian General Electric
Washington, D. C.	Instrument Society of Washington	W. A. Wildhack, National Bureau of Standards, Wash'n	Nov. 20(D)	Interior Dep't Auditorium	Precision Magnetic Compasses	Dr. A. G. McNish
			Dec. 11(D)	Interior Dep't Auditorium	Custom Calibrated Aneroid Inst's	Lester E. Demler
Whiting, Indiana	Whiting Instrument Men's Guild	Lloyd Clouse, 7344 Dante Ave., Chicago 19, Illinois				
Wyandotte, Mich.	Instrument Society of Wayne County	Wilson Fox, 33 Chestnut St., Wyandotte, Mich.	Nov. 26(D)	Monsanto Auditorium, Trenton, Mich.	Electrical Measuring Instruments	R. J. Tetzell, Westinghouse Central Div.

(A) Meeting at 7:30, no dinner (B) Dinner at 6:30, meeting at 8 (C) Dinner at 7, meeting at 8 (D) Meeting at 8, no dinner

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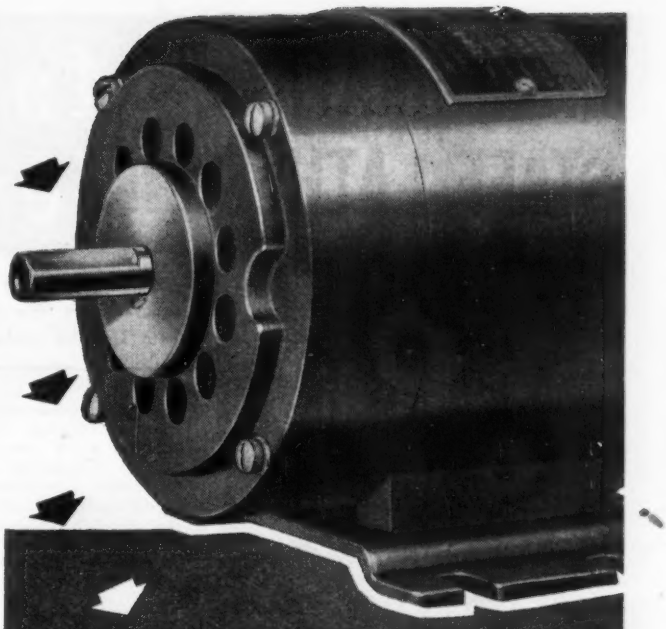

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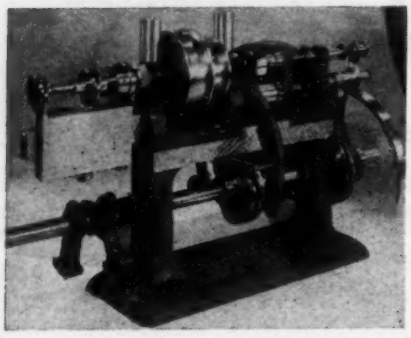

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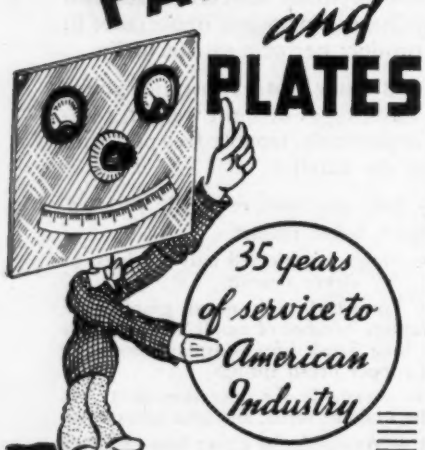

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Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the no-stamp-needed card on the facing page.

M-288 **Dimensional Quality Control Primer.** 26-page 6″ × 9″ booklet is described as a simplified method for applying statistical quality control to dimensions. Contents: (1) An explanation of dimensional quality control, (2) Additional advantages of dimensional quality control, (3) Simplified method of applying statistical quality control to dimensions, (4) Sampling procedure leading to the formation and use of quality control charts, (5) How to obtain the control limits, (6) Constructing the chart, (7) Interpretation and use of the charts, and (8) Supplementary methods and information useful in the application of quality control. Federal Products Corporation, Providence 1, Rhode Island.

M-289 **Machinists' Tools and Gages.** 4-page 8½″ × 11″ file folder pictures and describes the following improved tools: self-adjusting toggle clamps, A.S.A. drill bushings, machinists tools and gages which include depth micrometers, surfaces gages, screw pitch gages, thickness gages, engineers gages including wire, thickness and taper blades, and dupligage for drill hole inspection and utility. Products Engineering Co., 9045 Wilshire Boulevard, Beverly Hills, California.

M-290 **Communication Equipment for Aircraft.** 4-page 8½″ × 11″ pamphlet pictures and describes the "RTA-1B" communication equipment for aircraft which has been developed for the requirements of the air transportation industry. A complete general description of the equipment is given and transmitter and receiver specifications are listed in detail. Bendix Radio Division of Bendix Aviation Corporation, Baltimore 4, Maryland.

M-291 **Portable Type Pyrometers.** 4-page 8½″ × 11″ pamphlet pictures and describes the Huppert Lance type portable pyrometer as an instrument particularly adapted to reading the temperature of molten metals (exclusive of ferrous metals) and liquids. Also the Huppert prod-type portable pyrometer for hot, solid surfaces such as sheet metals, engine heads, castings, bearings, billets, etc. K. H. Huppert Co., 6830 Cottage Grove Avenue, Chicago 37, Illinois.

M-292 **"A New Era in Flow Rate Measurement."** 30-page 8½″ × 11″ Catalog Section 10-C, (third revised edition) discusses and illustrates the advantages of the rotameter for flow rate measurement. The contents cover high accuracy, linear flow curve, wide flow range, ready visibility of the metering elements and fluid, immunity of the rotameter to variations in viscosity and specific gravity, chemical corrosion resistance, low pressure loss and handling of condensibles. Fischer & Porter Co., 93607-C County Line Road, Hatboro, Pa.

M-293 **Hydraulic Pullers.** 6-page 8½″ × 11″ folder pictures and describes the center hole hydraulic puller as the jack which accelerates pulling of wheels, gears, keys, propellers, pistons, valve seats, wrist pins, bushings, cylinder liners, shafts, boiler tubes, pipe and ship stern tubes. It lifts, pushes or pulls and can be rigged up—as as press, to weigh, test or use as a conventional jack. Templeton, Kenly & Co., Chicago 44, Illinois.

M-294 **Viscometer.** 4-page 8½″ × 11″ pamphlet describes the function of the viscometer in taking up the job of motor protection where oil pressure and oil level gages leave off. Heat, cold, dilution, deterioration and all other factors that affect an oil's ability to lubricate are constantly checked. The instrument provides a scientific method for minimizing motor-wear. Visco-Meter Corp., 320 Grote St., Buffalo, N. Y.

M-295 **Negative Temperature Coefficient Resistance Material.** 4-page 8½″ × 11″ folder describes "Keystone NTC" resistance units with resistance values from 10 to 300 ohms at 25° C., having an average decrease in resistance with temperature approximately 1% to 2% per degree Centigrade. A temperature-resistance graph shows typical characteristics. Keystone Carbon Co., Inc., St. Marys, Penna.

M-296 **Anti-Capacity Switch.** 6-page 2½″ × 5″ leaflet pictures, diagrams and describes the anti-capacity switch used for many purposes where a quick change-over of several circuits is required; particularly suited also for experimental work in laboratories where multi-purpose apparatus is being built, also in production testing equipment. Federal Anti-Capacity Switch Corp., 1200 Niagara St., Buffalo, N. Y.

M-297 **"Apparatus Headliners."** 4-page 8½″ × 11″ pamphlet features a volumetric analyzer for quick carbon determinations in iron and steel laboratories. Accurate results (within two points in the second decimal place) are secured within two or three minutes after placing the boat in the combustion tube. Boder Scientific Company, 907-909 Penn Ave., Pittsburgh 22, Pa.

M-298 **Vibro-insulators.** 12-page 8½″ × 11″ booklet pictures and describes various types of rubber mountings for the elimination of vibration. In addition to many pictured applications and diagrams the descriptive matter covers: (1) Selecting the proper vibro-insulator, (2) Methods of mounting, (3) Applications, (4) Table of Characteristics, (5) Load-deflection curve to assist in selection of the proper mountings. B. F. Goodrich Company, Akron, Ohio.

M-299 **Electrical and Mechanical Equipment Catalog.** 226-page 8½″ × 11″ handbook of information, is also a catalog of aviation electrical and mechanical products, arranged with an introduction (Lear's background and pioneering in electro-mechanical aircraft control actuation) and seven sections covering each classification of products: (1) linear actuators, (2) rotary actuators, (3) power units, (4) screw jacks, (5) flexible power shafting and accessories, (6) motors, and (7) controls. All of the Lear products listed are fully illustrated, many with cutaway pictures showing the construction pattern. Installation drawings, operating curves, data tables, etc., are given in each section. Lear, Inc. Piqua, Ohio.

M-300 **Pressure and Flow Regulator.** 4-page 8½″ × 11″ pamphlet describes operation and characteristics of type

s O Regulator" for the control of suction, pressure or flow in any gas or air flow system. This instrument is used in connection with a power cylinder and a source of oil under pressure to control pressure in a wide variety of industrial applications. Precise regulation over a continuous range of pressures varying from a fraction of an inch water column to 50 lbs./in.² is claimed. Hagan Corp., Hagan Bldg., Pittsburgh, Pa.

M-301 **Differential Pressure Indicator.** 8-page 8½" × 11" Bulletin No. 1102 describes "Model 163" as a small, sturdy instrument, suitable for use with high static pressures and yet not subject to injury by extreme over-ranging. It is suited also to measuring rates of flow or liquid levels. The pressure-responsive element is a unique rupture-proof bellows unit, clamped between two pressure housings that surround opposite sides. This construction provides high and low pressure chambers, separated in effect by a frictionless piston. Suitable for high static pressures up to 3000 lbs./in.², the indicator can be calibrated for any differential pressure range from 0-50 lbs./in.². Barton Instrument Co., 2306 East 38th St., Los Angeles 11, Calif.

M-302 **"What's New in the World of Science."** 12-page 6" × 9" booklet helps explain and interpret a few of the new trends in scientific thinking and achievement. Eleven articles bring a closer understanding of this world in which we live, as revealed by the progress of our scientists. The articles are: (1) Smoke out, (2) Seeing is believing, (3) Artificial ocean, (4) Eleven years cooking, (5) Jumping steel, (6) It's a woman's war, too! (7) This handful flies high, (8) Talking in circles now, (9) Ringside or fireside seat, (10) For vast power, and (11) It's all done with mirrors. General Electric Co., Schenectady, N. Y.

M-303 **Twin Seal Check Valve.** 6-page 8½" × 11" folder pictures and describes the twin seal principle of valve control. It is composed of a metal-to-metal seat, plus a resilient ring seal on the poppet. When the valve is closed the shape of the poppet leaves a space into which the line pressure squeezes the resilient ring. The higher the pressure the tighter the seal, up to 10,000 lbs./in.². Suitable for water, air, oil, gas, etc.—any medium not destructive to rubber or synthetic rubber. Mansfield & Green, 4601 Euclid Ave., Cleveland 3, Ohio.

M-304 **"Synchro-Cyclic" Timer.** 2-page 8½" × 11" bulletin describes the on-off operation or cycling of circuits when required at repeated intervals. The instrument contains four relays which operate in consecutive and repeating order. Only one relay is energized at a time. Each relay is energized for a period of seconds, minutes, or hours as indicated by its corresponding adjustment arm setting. Applications include electrical and mechanical tests, "on-off" and multiple circuit cycling, food and chemical processing, and automatic oven and heater operation. Rowe Radio Research Laboratory Co., 2422 North Pulaski Rd., Chicago 39, Ill.

M-305 **New Uses for Vibrating Reed Frequency Meters.** 4-page 8½" × 11" Bulletin VF-43-1C describes the reed method for measurement of frequency, speed and vibration and the additional uses the reed instrument has been applied to. Pictured and described are 400-cycle aircraft portable, 400-3600-cycle model, lapsed time combination, resonant tachometer, radar field tester, 200-cycle production tester, 500-cycle production tester, special model for photography and telephony, and special model harmonic checker. J-B-T Instruments, Inc., 441 Chapel St., New Haven, Conn.

M-306 **"Theory of the Rotameter."** 24-page 8½" × 11" Catalog Section 98-Y covers history and technical development of area-type flowmeters and explanation of how patented Ultra-Stablvis

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rotameter overcomes the effects of viscosity and density in flow rate measurement. Under the heading "Analysis of Accuracy," the simplicity of the rotameter is brought out. Rotameter capacities and correction factors for liquids, gases and vapors are covered completely. This is a technical discussion of flow measurement. Fisher & Porter Co., 923-A County Line Rd., Hatboro, Pa.

M-307 **"The Connecting Link."** 4-page newspaper, the house organ of Link Aviation Devices (designated as Vol. 2, No. 3) contains many articles pertaining to aviation. Announced is the "Elementary Link Trainer" designed for school use. Link Aviation Devices, Inc., Binghamton, N. Y.

M-308 **Dials, Panels and Nameplates.** 8-page 8½" × 11" Bulletin 8145 describes and illustrates maker's facilities for manufacturing a variety of metal products, many of which are illustrated, including dials, data plates, nameplates, and panels for instruments and electric and electronic equipment, produced by lithography, etching and colorplating. L. F. Grammes & Sons, Inc., 379 Union St., Allentown, Pa.

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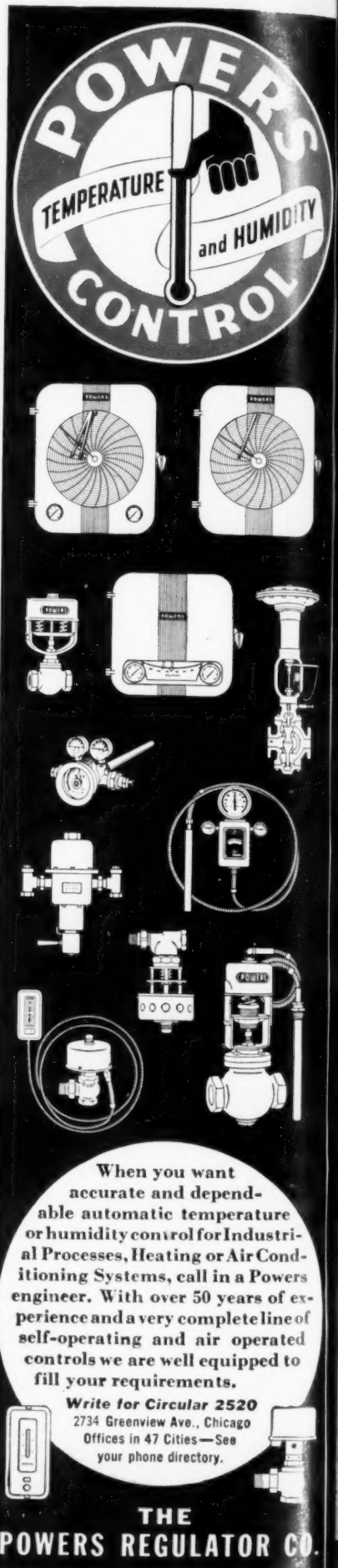
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